Volume 45. March, 1931. $4.00 a Year.
Number 1 — Part 1. Pages 1-88. $1.25 a Number.

JOURNAL

OF THE

New England Water Works Association.

(Prepared in two sections.)

Part 1.

ISSUED QUARTERLY.

PUBLISHED BY
THE NEW ENGLAND WATER WORKS ASSOCIATION,
714 Tremont Temple, Boston, Mass.

Entered as second-class matter September 23, 1903, at the Post Office at Boston, Mass., under Act of Congress of March 3, 1879.

Copyright, 1931, by the New England Water Works Association.

OFFICERS

OF THE

New England Water Works Association.

1930—1931.

PRESIDENT

GEORGE H. FINNERAN, Superintendent of Water Service, Boston, Mass.

VICE-PRESIDENTS

GEORGE W. BREHM, Metropolitan District Commission, Boston, Mass.
(Term expires September, 1931)

RICHARD H. ELLIS, Water Commissioner, Newton, Mass.
(Term expires September, 1932)

DIRECTORS

R. A. CAIRNS, City Engineer, Waterbury, Conn.
(Term expires September, 1931)

E. SHERMAN CHASE, of Metcalf & Eddy, Consulting Engineers, Boston, Mass.
(Term expires September, 1931)

HENRY F. HUGHES, Superintendent, Water and Sewer Department, Medford, Mass.
(Term expires September, 1932)

HOWARD M. KING, Superintendent, Water Department, Springfield, Mass.
(Term expires September, 1932)

PAST PRESIDENTS
(Members of Executive Committee)

FRANK E. WINSOR, Chief Engineer,
Metropolitan District Water Supply Commission, Boston, Mass.

ARTHUR D. WESTON, Chief Engineer,
Massachusetts Department of Public Health, Boston, Mass.

ROBERT SPURR WESTON, of Weston & Sampson, Consulting Engineers, Boston, Mass.

SECRETARY

FRANK J. GIFFORD, Superintendent of Water Works, Dedham, Mass.

TREASURER

ALBERT L. SAWYER, Water Registrar, Haverhill, Mass.

EDITOR AND ADVERTISING AGENT

GORDON M. FAIR, Harvard University, Cambridge, Mass.

THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

Initiation Fees		*Annual Dues*	
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	10.00

This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

A COMPACT OPERATION

Digging the trench. . .
Laying the pipe. . .
Backfilling. . .
Rolling in preparation for repaving.

ALL of these go on within a length of 200 feet or so of trench. The rapid succession of these different steps is possible because the joints of a Lock Joint Pressure Pipe Line of this size are calked and finished from the *inside*, after the pipe line has settled under the backfill to its final position.

The above is a photograph taken on the Wildcat Aqueduct of the Mokelumne System for the supply of the East Bay Cities, in California, built by the Lock Joint Pipe Company.

Lock Joint Pipe Co. - Ampere, N. J.

Established 1905

Pressure—Sewer—Culvert

LOCK JOINT
Reinforced Concrete
PRESSURE PIPE

LOCK JOINT PIPE CO. *Ampere — N.J.*

Table of Contents.

PAGE

Portrait of President George H. Finneran ..... Frontispiece

Disinfection of the Wanaque Aqueduct. By Attmore E. Griffin ... 1

Methods Attempted for the Prevention of Phenol and Other Tastes in the Water Supply of Rahway, N. J. By Mortimer M. Gibbons 6

Pollution of Reservoirs by Gulls and Other Birds. By G. C. Houser 15

Water-waste Prevention. By David A. Heffernan 21

Breaks of Water Mains, Service Pipes and Hydrants.—A Symposium. By Frank A. McInnes, Samuel E. Killam, Stephen H. Taylor, Frank A. Marston and George H. Finneran 23

Thawing Frozen Water Pipes. By George H. Finneran 44

Experiences with Water Mains and Cement-lined Pipe at Danvers, Mass. By Roger W. Esty 54

The Atlantic City Water Works. By Lincoln Van Gilder 66

Water Hammer in Pipe Lines. Its Causes, Manner of Action and Effects. By H. K. Barrows 72

Proceedings:

January Meeting 86

February Meeting 86

Obituary:

George Bowers 87

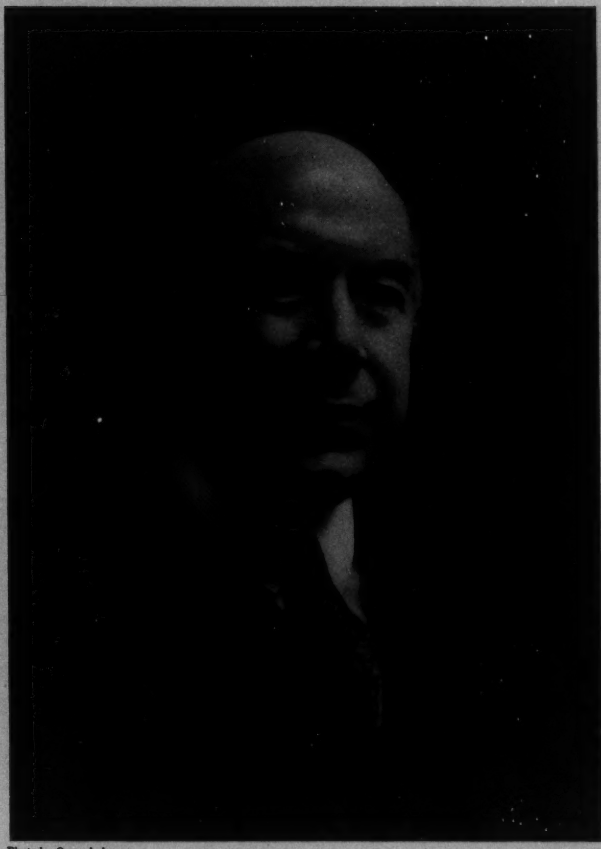


Photo by Oppenheim

GEORGE H. FINNERAN,
President of the New England Water Works Association,
1930-1931.

New England Water Works Association

ORGANIZED 1882.

Vol. XLV. March, 1931. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

DISINFECTION OF THE WANAQUE AQUEDUCT.

BY ATTMORE E. GRIFFIN.*

[*Read September 23, 1930.*]

In brief, this paper is an account of the successful use of the continuous-displacement method for disinfecting pipe lines and aqueducts, a method which is believed to be more convenient and safer than the method of filling and emptying, frequently employed.

The Wanaque Aqueduct begins at Raymond Dam which is situated in the borough of Wanaque, Passaic County, about 11 miles northwest of Paterson, N. J. The dam and aqueduct were constructed by the North Jersey District Water Supply Commission and sponsored by the municipalities of Newark, Paterson, Kearny, Passaic, Clifton, Montclair, Bloomfield and Glen Ridge. These communities and the city of Bayonne are or will be supplied with the water impounded in the Wanaque Reservoir.

The safe yield of Wanaque Reservoir is about 100 m.g.d. plus compensation water. Its capacity is 27 600 m.g. at El. 300. The main dam is 1 500 ft. long, about 190 ft. above bedrock with a core wall 20 ft. thick at the bottom tapering to 5 ft. at the top. The catchment area is 94.4 sq. miles and includes Greenwood Lake.

The aqueduct which will carry the vast volume of water to the various municipalities is approximately 20.5 miles in length. It is divided into a number of sections as follows:

The section beginning at the dam is a single 84-in. conduit, partly of reinforced concrete and partly of steel, 1 600 ft. in length. The aqueduct next divides into twin 74-in. steel lines running a distance of about 14 miles to the North Portal of Great Notch Tunnel, beyond which a single 74-in. steel pipe extends for 25 500 ft. to Belleville Reservoir. Great Notch Tunnel is lined with concrete. The finished section is 84 in. in diameter and 9 000 ft. long.

The steel pipe when completed was clean. All riveted joints had been repainted with asphaltic paint; the bottom had been swept clean, and a strip about 18 in. wide upon which the workmen had walked had been repainted with asphaltic paint. Thus there was no accumulation of dirt to contend with. Furthermore, the pipe had been laid almost immediately

*Analyst in charge of Wanaque Laboratory, North Jersey District Water Supply Commission, with Weston & Sampson, Consulting Engineers, Boston.

upon arrival on the job, so that little opportunity had been given for accumulation of dust and débris.

The contract for the steel part of the aqueduct specified that, "upon completion the interior of the aqueduct shall be sterilized, then filled with clean, potable water preparatory to placing it in service."

For disinfection the contract specified the use of 2½ lb. of chloride of lime for every 100 lineal ft. of 74-in. pipe line. This is equivalent to approximately 3.2 p.p.m. of available chlorine, using commercial bleach having not less than 24 per cent. available chlorine.

The use of chloride of lime on a pipe line of this magnitude did not appeal to the contractors who desired to substitute liquid chlorine introduced at a single point. Their plan was approved, and accordingly, two manually-operated chlorinators, each capable of delivering 4 p.p.m. of chlorine to 10 m.g.d. of water, were installed in the upper gatehouse at Raymond Dam.

The general plan of disinfection was to add for the first few hours about 8 p.p.m. of chlorine to the flowing water, followed by reduction of dosage to about 4 p.p.m., and its continued application at this rate until a minimum of 2 p.p.m. available chlorine arrived at the end of the line at Belleville Reservoir; the water flowing through the aqueduct at a rate of 10 m.g.d. In general, this plan was carried out. Expectations were exceeded, however, and 3.0 p.p.m. available chlorine were obtained at the Belleville end of the line.

On February 19, 1930, the date set for beginning the disinfection of the pipes, there were no recording meters at any point on the line between Raymond Dam and the Passaic River into which it was intended to waste water in order to maintain a flow of 10 m.g.d. It was estimated that an 8-in. blow-off at the Passaic River would discharge at about the desired rate, but to check this an oil-type manometer, filled with kerosene of specific gravity 0.789 and giving readings 4.985 times greater than an air-type manometer, was placed on the 84 x 48-in. Venturi meter at the dam. The readings on this manometer checked very well with the recording meters which were later installed near Belleville. As a matter of fact, the manometer is still in use in connection with the operation of the temporary chlorine machines.

With flows thus controlled, the chlorinators were started at 10:55 A.M., February 19, 1930, at a 7-p.p.m. rate. This was maintained for 3 hours and 35 minutes, until 2:30 P.M., when the dose was reduced to 4 p.p.m. On the next day, 6 p.p.m. of chlorine were found in the aqueduct and continued to be recorded for two full days, travelling a distance of 23 700 ft. during this time. During the next two days the free chlorine in the water was reduced to 4 p.p.m. and travelled another 23 000 ft. to Station 498, 8.8 miles from the dam. From this point on the free chlorine maintained itself at 3 p.p.m. to the end of the line, 20.5 miles from the dam, where it arrived at 3:40 P.M. on the 24th. Thus it took the heavy dose of chlorine 5 days, 4 hours and

45 minutes to make the journey of 20.5 miles. This was very close to the computed time and equivalent to 870 ft. per hour.

It was planned to drain off this heavily chlorinated water immediately and replace it by clean, potable water, but alterations in a blow-off chamber on the line connecting with Kearny necessitated the closing of the aqueduct for about a day. This gave an opportunity to check the amount of residual chlorine in the pipes between Belleville and the dam. It was found that 3 p.p.m. of chlorine persisted northward from the end of the line to the North Portal of Great Notch Tunnel. From here northward to the dam the residual chlorine approximated 1.0 or 1.5 p.p.m. in each of the twin lines.

After a lapse of 24 hours, the heavily chlorinated water was drawn off and replaced by clean, potable water from the reservoir, chlorinated at the anticipated service rate of 0.35 p.p.m. As fast as the chlorinated water was replaced, bacterial samples were collected at about 2-mile intervals. As a final check, half-hourly samples were collected during eight hours at the end of the line after all the heavily chlorinated water had passed.

Not a single colon bacillus was found in about forty samples collected. The highest total count on agar incubated for 24 hours at 37.5° C. was 5 colonies per cc. It was therefore concluded that disinfection had been complete.

The quality of the water during the whole operation was most favorable to chlorination. Its chlorine demand was very low, not exceeding 0.10 p.p.m. Later in the year, the raw water gave a false chlorine reading with ortho-tolidin as high as 0.24 p.p.m. and had an apparent demand approaching 0.30 p.p.m.

For testing the amount of residual chlorine, ortho-tolidin was used. The standards were prepared in the laboratory. Since chlorine standards above 1.0 p.p.m. in strength are rather inaccurate, all samples were diluted with distilled water so that they could be compared with standards reading lower than 1.0 p.p.m.

The usual practice in the disinfection of pipes and aqueducts is to fill them with heavily chlorinated water and allow them to stand for 24 to 48 hours. In the Wanaque Aqueduct, continuous operation secured the desired contact during the ten days of filling and emptying, so that all parts of the pipe were in contact with the chlorinated water for at least five days.

In conclusion, the author expresses his appreciation of the kindness and assistance of J. A. Ward, who directed the hydraulic work.

Discussion.

E. Sherman Chase.* About three years ago, at the time of the completion of the airplane carrier *Lexington*, the necessity arose for the contractors to disinfect the water-main distribution system and the tanks for the potable water supply on board the ship. This disinfection was called for in the contract. Disinfection was carried out under our direction, and the procedure is interesting with reference to water-main and aqueduct disinfection.

In order to afford ample free chlorine for disinfection and to avoid at the same time any possible corrosive action of the disinfecting agent, it was decided to use about 50 p.p.m. of free chlorine and to allow a period of contact of twelve hours or more.

A solution of chloride of lime was prepared by adding 275 lb. of chloride of lime to an auxiliary tank containing about 650 gal. of water. The mixture was thoroughly agitated by means of compressed air to effect complete solution of the calcium hypochlorite. The mixture was then allowed to settle. The clear top water, free from particles of lime and all other materials, was used for preparing the disinfecting solution.

An amount of the chloride of lime solution sufficient to make a uniform disinfecting solution of the desired strength was added gradually to Gravity Tank No. 1, one of the tanks connected with the distribution system, while it was being filled with water from the water-supply system of the shipyard. This solution was then drawn off to one of the storage tanks in the hold. The gravity tank was then refilled, and the solution was drawn off to the storage tank, as before. This process was repeated until the storage tank was full.

While the storage tank was standing full, the second storage tank was filled in like manner with a disinfecting solution. The third storage tank was filled by pumping into it the disinfecting solution from the first storage tank, after adding from the gravity tank to the third tank a solution of sufficient strength to bring the disinfecting solution up to the desired strength.

Gravity Tank No. 1 was again filled with the sterilizing solution, which was then drawn into the pipe lines connected with it, the taps and faucets all through the ship being kept open until the air had been expelled and water having a chlorine taste was discharged. In this way the pipe lines were completely filled with the disinfecting solution and allowed to stand full.

Gravity Tank No. 2 was also filled with a disinfecting solution, because men had worked in it after the strong solution of chloride of lime had been drawn off.

After each preparation of disinfecting solution in the gravity tank,

*Of Metcalf and Eddy, Consulting Engineers, Boston.

samples were drawn off through a pet cock in the tank and tested to make sure that the solution contained the desired amount of free chlorine. As fast as each of the storage tanks in the hold were filled, a sample was taken from the pet cock and tested to determine the initial chlorine content. After standing longer than a period of twelve hours, which was stipulated in the specifications, another sample was taken from each tank and tested to determine the residual chlorine content.

After disinfecting the piping from Gravity Tank No. 1, the free chlorine in the solution, after standing longer than the required period, showed that complete disinfection of the tanks and piping had been secured.

The results obtained showed that after a contact period of nearly 24 hours there was still a substantial amount of free chlorine in the water at all points throughout the distribution system of the ship.

METHODS ATTEMPTED FOR THE PREVENTION OF PHENOL AND OTHER TASTES IN THE WATER SUPPLY AT RAHWAY, N. J.

BY MORTIMER M. GIBBONS.*

[*Read September 25, 1930.*]

The city of Rahway obtains its water supply from the Rahway River which rises in the Oranges and empties into the Arthur Kill. The watershed of this river has an area of about 40 sq. miles and contains about 75 miles of stream. Several residential cities and a few industrial communities are included in the watershed. A survey conducted by the New Jersey State Department of Health[1] in 1916 indicated that the population per sq. mile was close to 1 000. It has increased materially since that date. There were about 40 factories on the watershed at that time. The flow of the Rahway River varies from about 5 m.g.d. to upwards of 200 m.g.d. during heavy run-off. The average flow is about 20 m.g.d.

Water Works. The water for municipal use is taken directly from the river about two miles above tidewater and is treated in a modern rapid-sand filter plant. The treatment processes consist of coagulation with sulphate of alumina, mixing through low-lift pumps and influent aërators, a detention period of about 6 hours in the coagulation basins, passage through rapid-sand filters, chlorination and final aëration. The purified water is pumped directly to the city. There is a steel storage tank for the final effluent which acts as a balancing reservoir. Its capacity is small, however, and it is not possible to shut down the filter plant for more than a few minutes without causing distress in the city. In 1927, the water plant was renovated and new filters were installed under the direction of Hazen & Everett, Engineers, New York.

Character of River Water. The river water is characteristic of surface waters in this section and is of moderate turbidity, color and hardness. (See Table 1.) It contains an adequate supply of dissolved oxygen. However, appreciable quantities of industrial wastes have been entering the stream. The most troublesome of these wastes were from the manufacture of organic chemicals. These contained phenols, aniline and organic solvents. Waste water containing chlorine has also been emptied into the river. In recent years mash and fermenting wastes incident to the manufacture of alcohol have at times been discharged into the stream.

Medicinal Taste in City Supply. The main source of taste-producing wastes entering the river has been a plant manufacturing organic chemicals and discharging waste water containing phenols and aniline. With the coöperation of the State Board of Health, a waste-treatment plant was

*Water Works Chemist, Rahway, N. J.

TABLE 1. — ANALYSIS OF RAHWAY RIVER AT WATER WORKS FOR YEAR 1929.

	Average.	Maximum.	Minimum.
Turbidity, p.p.m.	25	250	4
Color, p.p.m.	35	200	16
Alkalinity, p.p.m.	64	92	15
pH	7.3	8.0	6.8
Oxygen consumed, p.p.m.	6.7	68.4	2.8
Bacteria per cc. on Agar, 37° C.	850	27 000	70
B. coli index per 100 cc.	3 360	100 000	10

installed at this factory about ten years ago. However, several years' operation of the treatment plant clearly proved that adequate protection of the Rahway water supply could not be obtained by this method. The pollution from this source has been sufficient to cause a chronic unpleasant, woody taste in the city water and has alienated many consumers from the municipal supply for drinking purposes. At times, especially during the colder months, medicinal tastes have prevailed for several days in a stretch. The river water has often had a medicinal taste before treatment. These periods of disagreeable taste have occurred with both high and low flows in the river. The effect of dilution in eliminating taste trouble from chemical pollution has been slight, probably because the source is only a few miles above the water plant and the time for oxidation of impurities is short. During the winter and spring months, when the medicinal tastes have been most severe, biological activity in the stream is also retarded.

After the purification plant was renovated in 1927, a final effluent free from appreciable turbidity, color and bacteria was produced. However, the taste and odor of the water still caused complaint by the consumers. Several taste-preventive treatments were then investigated.

Taste Removal in Rapid-sand Filters. A series of comparative taste tests on water at various stages of purification was started in order to see what taste removal was accomplished in the plant and where it occurred. (See Table 2.) Raw water, coagulated water and filter effluent were each treated with 0.5 p.p.m. chlorine, allowed a contact period of two hours and then tasted. Unchlorinated filtered water was also tasted.

TABLE 2.— SUMMARY OF MEDICINAL TASTE IN WATER AT VARIOUS STAGES OF PURIFICATION 1928–1930.

No. of days tests were made.	Medicinal Taste — Days.				Per cent. time sand filtration removed medicinal taste from coagulated water.	Av. rate sand filtration (est.) m.g.a.d.
	In filt. water prior to chlor.	In raw water plus 0.5 p.p.m. chlorine.	In coag. water plus 0.5 p.p.m. chlorine.	In filt. water plus 0.5 p.p.m. chlorine.		
497	13	42	64	19	70	75

NOTE. Raw water, coagulated water and filtered water were each dosed with 0.5 p.p.m. chlorine, allowed a contact period of two hours and then tasted.

These taste tests were made frequently over a period of two years. At all times, the filtered water had the least objectionable taste. Occasionally, the raw water and coagulated water upon chlorination would have a medicinal taste, while the chlorinated filtered water would have a woody taste, much less unpalatable than the medicinal one. Presumably, the biological purification of the water in passing through the sand filters lessened the taste. A medicinal taste was present more often in the coagulated water upon chlorination than in the chlorinated raw water. The greater content of nitrogenous organic matter in the raw water may have had the effect of preventing medicinal tastes in some instances. Whatever the cause, this property has been of value in comparing river samples for taste-producing powers. By treating each river sample with sufficient filter alum to coagulate it, allowing it to settle and decanting or filtering through paper before chlorination, a more delicate test for medicinal taste has been obtained than by chlorinating raw water.

At times, raw-, coagulated- and filtered-water samples upon chlorination would develop a medicinal taste, less pronounced in the filtered sample than in the other two. During our worst periods when the river water prior to plant chlorination had a medicinal taste, all three samples upon chlorination had a pronounced medicinal taste. During the summer months, a woody taste was present in all three samples, more pronounced in the raw and coagulated water than in the filtered effluent.

The results of these tests indicate that rapid-sand filtration under the conditions existing at Rahway is a distinct aid in reducing the medicinal, taste-producing properties of the applied water. Filtration has made the water less unpalatable by absorbing potential medicinal taste from the applied water on 45 days out of 64 in the period considered. The average rate of filtration has been about 75 m.g.a.d.

Superchlorination Treatment. Following Howard's[2] successful use of superchlorination at Toronto, some laboratory taste-tests using small doses of carbolic acid in filtered water plus varying quantities of chlorine were made. These indicated that 1.0 to 1.25 p.p.m. chlorine would prevent a medicinal taste. This dose of chlorine was then tried in the plant during January, 1928. Chlorine was applied to the water after filtration and a contact period of about two hours was obtained in the pure well. The effluent from the pure well was completely dechlorinated with sulphur dioxide. The characteristic woody taste in the water was not materially improved, and after a heavy run-off a decided medicinal taste developed in the supply. Obviously, the optimum chlorine dose determined when using carbolic acid in various dilutions in the laboratory was not a safe guide for plant treatment.

Profiting by Howard's[3] advice after this experience, the chlorine dose was increased to 2.0 to 3.0 p.p.m., and a check was maintained on the amount of residual chlorine after two hours' contact. (See Table 3.) Moreover, a sample of the wastes causing the taste trouble was used in laboratory

TABLE 3.— SUMMARY OF SUPERCHLORINATION TREATMENT AT RAHWAY FILTRATION PLANT.

Period used.	No. of days.	Range of water temp. - °F.	Chlorine Dosage. p.p.m.			Residual Chlorine after 2 hours' contact. p.p.m.			Taste of water after complete dechlorination with sulphur dioxide.
			Av.	Max.	Min.	Av.	Max.	Min.	
1928 Jan. 19 to Feb. 13	25	34–40	1.0	1.2	0.7	...	...	...	Faint woody. Decided medicinal for five days.
Mar. 12 to Mar. 22	10	40–44	2.0	2.7	1.8	...	...	...	Faint woody. Faint medicinal for two days.
Mar. 22 to Mar. 29	7	42–51	2.6	2.7	2.5	1.7	1.9	1.4	Faint woody.
Apr. 7 to July 18	102	44–75	2.3	2.9	1.4	1.2	1.8	0.5	Faint to distinct woody. Musty, especially in city.
Oct. 2 to Dec. 24	83	37–55	2.6	3.1	2.3	1.9	2.4	1.0	Distinct woody. Faint medicinal for 3 days on 2 separate occasions. Musty, especially in city.
1929 May 4	1	55	3.5	...	...	1.0	...	...	Distinct medicinal.

tests for chlorine consumption. Unfortunately, we were to learn later that the wastes varied widely in concentration from day to day. This higher dosage of chlorine was used on a plant scale for nearly four months. In conjunction with the taste removal occurring during filtration, it aided in preventing a medicinal taste in the supply when chemical pollution was not excessive. However, the improvement in the woody taste was slight, and there was considerable complaint from consumers of a musty[4] side taste, more apparent in the city than at the water plant.

During the summer when medicinal tastes are not usually prevalent, superchlorination was temporarily discontinued. It was again used in the fall for nearly three months. The chlorine dose varied from 2.3 to 3.1 p.p.m. At all times there was a minimum of 1.0 p.p.m. residual chlorine after two hours' contact. On two separate occasions in this period, a medicinal taste occurred in the city supply despite superchlorination. At these times, there was a medicinal taste in the water coming to the plant. Laboratory tests on these days indicated that 10.0 p.p.m. chlorine would not remove the medicinal taste from the filtered water.

On one further occasion superchlorination was tried for one day during a very bad taste period. The water coming to the plant again had a medicinal taste. A chlorine dose of 3.5 p.p.m. was used, and a residual of 1.0 p.p.m. chlorine after two hours' contact was present. A distinct medicinal

taste developed despite this treatment. Laboratory tests at this time indicated that 10.0 p.p.m. chlorine would not remove the medicinal taste from the filtered water.

During superchlorination treatment, the water was dechlorinated with sulphur dioxide after two hours' contact by applying the dechlor in the main immediately prior to final aëration. The reaction appeared to be practically instantaneous, and any slight excess of sulphur dioxide was removed by aëration. However, it was decided to try applying the sulphur dioxide after aëration. It was hoped that the sulphur dioxide consumption could be materially reduced or possibly eliminated. The aërators are enclosed in a two-story building with windows on all sides and a skylight in the roof. All the windows and the skylight were open when the test was made. The aërators are of the spray-nozzle type and operate under a head of about 10 ft.

The chlorinated water after a two-hour contact period had a residual chlorine content of 1.6 p.p.m. At the start, aëration reduced this to 0.7 p.p.m., or more than 50 per cent. reduction. At the end of one hour, the residual chlorine after aëration was 1.0 p.p.m. The residual chlorine after aëration gradually increased until, after three hours, there was no reduction in chlorine content. The chlorine gas, being heavier than the air, hung over the water, and very little dispersion of the gas was effected by the ventilation obtained from open windows. Consequently, after a few hours there was no interchange of chlorine between the water and the air. Doubtless with the aid of fans to remove the chlorine gas continuously from above the water, the residual chlorine content of the water could have been reduced about 50 per cent. by aëration. However, this was not attempted at Rahway, because the superchlorination treatment was only experimental and also because metal objects in an adjacent building would be seriously corroded.

Ammonia and Chlorine Treatment. Several laboratory experiments using ammonia and chlorine treatment were made both by Howard and the writer. Filtered water was dosed with the wastes causing the taste trouble in such manner as to simulate the dilution obtaining in the river. Varying amounts of ammonia and chlorine were then added to these prepared samples. From 0.1 to 0.5 p.p.m. ammonia was used and the chlorine dosage varied from 0.1 to 1.0 p.p.m. The ammonia was added to the water about fifteen minutes before the chlorine, and a contact period of two hours was allowed before tasting. The samples were then allowed to stand overnight and again tasted. None of these combinations of ammonia and chlorine was successful in preventing a medicinal taste from developing in the samples.

On several occasions when the filtered water in the plant had a medicinal taste, samples of the filter effluent were treated with ammonia and chlorine in the laboratory. However, no combination of ammonia and chlorine was obtained which destroyed the medicinal taste. When filtered water which had a woody taste was treated with ammonia and chlorine,

there was a slight reduction in the intensity of the woody taste except during periods of heavy run-off when little improvement was effected. Ratios of ammonia to chlorine of 1 to 5 and up to 1 to 10 gave beneficial results in some instances. From 0.1 to 0.2 p.p.m. of ammonia was used. On the whole, this treatment did not seem to be adapted to combating the type of chemical pollution existing at Rahway.

Potassium Permanganate Treatment. Potassium permanganate was used on a plant scale for about ten days during a period when the raw water prior to treatment had a medicinal taste. The potassium permanganate was applied at the entrance of the coagulation basin, and a contact period of about six hours was obtained before filtration. The quantity added varied from 0.65 to 1.43 p.p.m. potassium permanganate. On four days in this period, sufficient permanganate was applied to impart a faint pink tinge to the water after six hours' contact. (See Table 4.) During this

TABLE 4.— SUMMARY OF POTASSIUM PERMANGANATE TREATMENT AT RAHWAY FILTRATION PLANT.

Period used.	No. of days.	Range of water temp. ° F.	POTASSIUM PERMANGANATE DOSAGE. p.p.m.			Contact hour.	Taste of water after sand filtration and prior to chlorination.
			Av.	Max.	Min.		
1929 Oct. 3	1	59	0.40	....	....	6	Faint medicinal.
Dec. 9 to Dec. 19	10	33–39	1.12	1.43	0.64	6	Decided woody and faint medicinal.

NOTE. After six hours' contact in period December 9–19, water had slight pink tinge on four days.

period the filtered water after permanganate treatment but before chlorination had a faint medicinal taste. After a chlorine dose averaging 0.17 p.p.m., the water retained the medicinal taste without perceptible difference in intensity. In the city, however, the medicinal taste seemed slightly stronger than at the plant. Although at this period the plant was not equipped for prechlorination, laboratory tests using 0.5 p.p.m. chlorine added prior to 1.0 p.p.m. potassium permanganate did not remove the medicinal taste from the water.

The permanganate treatment has been of value in reducing a fishy taste due to *Synura* when applied in quantities of about 1.0 p.p.m. and allowed a six-hour contact period before filtration.

Activated-carbon Treatment. An experimental unit containing "Hydrodarco," an activated-carbon filtering material, has been in operation for more than six months through the courtesy of the International Filter Company of Chicago. This filter is 16 in. in diameter and contains a depth of 2 ft. of activated carbon. The material has the consistency of very coarse sand. This unit has been treating city water which has been filtered and

chlorinated. The chlorine dose has averaged 0.40 p.p.m., and the residual chlorine has varied from 0.05 to 0.10 p.p.m. The filter has been operated at a rate from 3 to 5 gal. per sq. ft. per min., and has been used in upward and downward filtration. The average rate has been 4 gal. per sq. ft. per min. (See Table 5.)

TABLE 5.— SUMMARY OF RESULTS FOR EXPERIMENTAL "HYDRODARCO" ACTIVATED-CARBON FILTER AT RAHWAY FILTRATION PLANT.

Period used.	No. of days.	Range of water temp. ° F.	Rate of filtration gal. per sq. ft. per min.	Medicinal Taste — Days.			Taste of activated-carbon filter effluent.
				In filt. water prior to chlor.	In filt. water plus 0.4 p.p.m. chlorine (tap).	In effluent from activ.-carbon filter.	
1930 Jan. to Aug.	212	33–75	4.0	4	5	0	Characteristic taste is faint flat, faint woody taste when tap had medicinal taste.

NOTE. Influent to activated-carbon filter was the effluent from rapid-sand filters plus an average dose of chlorine of 0.4 p.p.m.

During the period that this filter has been in operation, there have been a few days when a medicinal taste was present in the city supply. The effluent from the activated-carbon filter has been free from medicinal taste when operated at a rate of 3 to 4 gal. per sq. ft. per min. Above 4 gal. per sq. ft. per min. there has not been sufficient contact of the water with the carbon particles to remove the medicinal taste entirely. On some of the days when a medicinal taste has been in the city supply, a similar taste has also been present in the river water prior to treatment. On these days, the effluent from the activated-carbon unit has had a faint woody taste. The characteristic taste of this effluent is slightly flat. Occasional tests indicate that the dissolved oxygen content is high. This type of treatment has been the most successful of all those tried at Rahway to remove medicinal tastes. However, our experience with activated-carbon filtering material has not been of sufficient duration to determine how great the deterioration in its adsorptive capacity may be. Consequently, a rate of filtration between 3 and 4 gal. per sq. ft. per min. which has been successful in removing medicinal taste up to the present is only tentative and might be subject to downward revision. Activated carbon at the rate of filtration used here has not been completely successful in removing another taste mentioned later.

Taste Trouble from Molasses Wastes. During the early part of January, 1929, the color in the river water increased from 25 p.p.m., a normal color for this season, to 70 p.p.m., and a distinct sweet odor was present in the water. It was not possible to reduce this color to less than 20 p.p.m. in the final effluent, although the alum dosage was increased fivefold to 5.0 grains

per gal. The sweet odor persisted in the city water after filtration and double aëration.

A hasty investigation upstream disclosed that spent molasses was entering the stream, coming from an apparently unused factory building. Further investigation revealed that an illicit distilling plant was discharging the molasses wastes into the river. With the coöperation of the federal authorities, this establishment was raided and destroyed. In demolishing this plant, huge vats of molasses were accidentally allowed to flow into the river. The color of the river water at one time rose to 200 p.p.m., and the oxygen consumed value was about 70 p.p.m. It was not possible entirely to remove this heavy pollution in the treatment plant, and for a short period the city water had a high color and foamed copiously when drawn from the tap. It had a sickly sweet odor and was practically undrinkable.

Taste Trouble from Fermenting Wastes. Another source of disagreeable taste in the city water has been pollution by mash and fermenting wastes incident to the manufacture of alcohol. These wastes have not affected the appearance of the river water but at times have imparted a bitter alcoholic taste and odor to the water, even after treatment in the purification plant. On two or three occasions during the winter of 1930 following a heavy run-off, this taste has occurred and persisted for several days. Each time the source of the taste was traced to storm-water drains entering the stream many miles above the water plant. The drains containing the waste water were then located and plugged.

The waste water was clear and of low color when first collected. However, it had a musty odor of decomposition, and upon standing a few hours it became cloudy and colored, and a precipitate of organic matter settled out. Examination of the liquid under the microscope revealed numerous yeast cells. These wastes vary widely in their power to impart taste to water, apparently depending on the predominating yeasts or bacteria in the liquid. The temperature and biological activity in the river water also appear to influence the taste-producing properties of these wastes. Our worst trouble has occurred during the colder months, when natural purification of the river is retarded.

We have not had much success in removing this bitter alcoholic taste in the plant. Aëration before and after sand filtration reduced the intensity of the taste to some extent, but the taste of the final effluent was still very bad. Even our activated-carbon filter which has been successful in removing medicinal taste, was unable at a rate of 3 to 4 gal. per sq. ft. per min. entirely to remove this taste. However, it did reduce the intensity of the taste somewhat, and it is possible that in conjunction with superchlorination[5] an activated-carbon filter operating at this rate will remove the taste completely.

Another promising method for combating this taste is that recommended by Spalding[6] and consists in adding finely pulverized activated carbon with the coagulant and obtaining contact with the water as the floc

settles out in the basin. By this method, the entire supply could be treated without filter installation, and the activated carbon applied would always be fresh. We hope to try this treatment if another such taste period occurs.

Prevention of Industrial-wastes Pollution. The various disagreeable tastes experienced at Rahway and the limited success of present methods for removing them emphasize the importance of controlling industrial-wastes pollution. Regular river inspections and periodical examination of feeder water have aided us in obtaining some relief. Several minor wastes have been detected and have been diverted from the stream by coöperation with the industries affected. Pollution by fermenting wastes is very difficult to prevent. These wastes are discharged intermittently and, because of their nature, the source is unknown until after the damage has been done.

It has been necessary to resort to litigation to stop our major source of taste trouble,— pollution of the stream by wastes containing phenols and aniline. With the coöperation of the State Board of Health legal action has been taken against the offending plant. This necessarily requires some time during which several bad tastes have occurred. However, this policy is fundamental to obtaining permanent relief, because the chemical pollution has been so severe that it could not be removed by treatment readily applicable to the entire supply.

REFERENCES.

[1] New Jersey State Board of Health. Sanitary Survey of Rahway Watershed, 1916.

[2] Howard and Thompson. Chlorine Studies, Jour. N.E.W.W.A., Sept., 1926. Vol. 40, No. 3.

[3] Howard, Norman J. Report to Hazen & Everett on Taste Conditions at Rahway, N. J.

[4] Cf. Bay City Experience. Harrison, Louis B. *Jour. A.W.W.A.*, April, 1929. Vol. 21, No. 4.

[5] Suggested by A. S. Behrman of International Filter Co.

[6] Spalding, George R. Activated Char as a Deodorant in Water Purification, *Jour. A.W.W.A.*, May, 1930. Vol. 22, No. 5.

POLLUTION OF RESERVOIRS BY GULLS AND OTHER BIRDS.

BY G. C. HOUSER.*

[*Received January 30, 1931.*]

In recent years much has been written about the protection of surface water supplies from pollution by domestic sewage and industrial wastes as well as by campers, motorists, woodcutters and so forth. In Massachusetts, there has been considerable agitation lately among those charged with maintaining the purity of surface supplies, on account of the hazard of pollution of open reservoirs by birds; and particularly by sea gulls. The 1931 session of the legislature has under consideration a bill to legalize the shooting of gulls over water-supply reservoirs in order to preserve the purity of the water.†

The pollution of reservoirs by sea gulls and other birds has by no means been confined to Massachusetts, but has been recorded at various other points in the United States, and in Canada, Great Britain and Central America. On the Pacific Coast of North America, three cities in particular have had trouble of this sort: Victoria, B. C., (1) and San Francisco (2) and Los Angeles, Cal. At San Francisco (3), trouble with sea gulls made it necessary to cover one of the distributing reservoirs in 1919, and all reservoirs built since that time have been covered. At Los Angeles (4), during the fall it is a common occurrence for 10 000 or more gulls to rest on one of the reservoirs at night, and the best results in the way of protecting the water supply have been obtained by shooting at the birds to drive them from the lake. These measures have also been successful at Spot Pond and Chestnut Hill Reservoir of the Boston Metropolitan Water Works (5), (6).

Not only sea gulls but pigeons and other birds have caused difficulty. At Lafayette, Ind. (7), an investigation by the State Board of Health indicated that pigeons which had access to a reservoir were causing contamination of the water supply, and it was recommended that the reservoir be tightly covered. At Panama (8), birds were considered responsible for the seeding of a low-service reservoir with algæ, which developed into a nuisance; the trouble was not eliminated until the reservoir had been covered.

At New York City (9), from the end of August until the following April, sea gulls flock to Hillview Reservoir, at times numbering thousands. The effect of the gulls on the pollution of the supply has been evident in the late summer and fall, as shown by the average *B. coli* content during this period in comparison with the remainder of the year when the gulls are not present. Experiments carried out in the laboratory of the analyst for the city of

*Assistant Engineer, Metcalf & Eddy, Boston, Mass.

†This bill was signed by the Governor on February 12, 1931. (Chapter 21, Acts of 1931.)

Dundee, Scotland (10), have shown that it is reasonable to estimate that 100 gulls will contaminate a reservoir holding 100 m.g. of water to the extent of giving a positive reaction for *B. coli* in 40 cc. of the water. The Metropolitan Water Board of London (11), which has had considerable difficulty with gulls, estimates from the results of a practical test that each gull may contribute 50 to 100 million *B. coli* per day to a water works. A photograph

ROCK IN CAPE POND, ROCKPORT, MASS., SHOWING GULL DROPPINGS.
Standpipe and Pumping Station in Background. October, 1926.

of one of the rocks in Cape Pond at Rockport, Mass., accompanies this paper and gives some indication of the extent to which this reservoir is contaminated by gull droppings.

In England, about three years ago, B. A. Adams (12) isolated the typhoid bacillus from gulls' excreta collected in the vicinity of a town where typhoid epidemics had occurred. In this way he demonstrated the possibility of the spreading of typhoid fever by gulls which pollute water-supply reservoirs. From an esthetic standpoint, it is also desirable to keep gulls away from reservoirs, for people do not like to think that they are drinking water polluted by the excreta of birds which may have been feeding in the vicinity of sewer outlets. It should, therefore, be made lawful to shoot gulls in order to prevent large flocks of these birds from lingering in the vicinity of water-supply reservoirs.

APPENDIX.

(1) Solving the Sea Gull Problem in San Francisco. G. W. Pracy. *Jour. A.W.W.A.*, 17: 4, 466, Apr., 1927.

About ten years ago the sea gulls started coming into one of our small reservoirs not far from the water front. They became so bothersome that we finally covered the reservoir. The birds then spread to three larger reservoirs farther in town. We tried to drive the birds away by shooting and finally purchased an automatic exploder which was only fairly successful.

The city of Victoria, B. C., had had trouble with sea gulls and had effected a cure by stringing wires across the reservoirs in about 50-ft. squares. We tried this on one of our reservoirs, and finally on all three, stringing the wires 40 ft. apart in both directions. The wires are pulled taut, the net work of wires being about one foot above the high-water mark in the low part of the span. The results have been entirely satisfactory. We get an occasional sea gull, but they appear rarely and they do not stay.

(2) The San Francisco Water Supply. G. A. Elliott. *Jour. A.W.W.A.*, 20: 3, 294, Sept., 1928.

The principal sources of trouble in sanitation have been some of the city distributing reservoirs where sea gulls, which are protected by state game laws, made a practice of spending part of their time. All ordinary means failed to control this nuisance until finally wires were strung across the surface of the water at intervals of about 40 or 50 ft. each way and about 3 to 5 ft. above the surface. For some unknown reason these birds will not fly down into a reservoir protected in this manner.

(3) Design and Construction of Concrete-lined Distributing Reservoirs. I. E. Flaa. *Jour. A.W.W.A.*, 15: 2, 118, Feb., 1926.

In the earlier years of the development of the Spring Valley Water Company it was found unnecessary to cover distributing reservoirs to eliminate contamination from algæ or other sources, but in the past 20 years the sea gulls have increased in great numbers and seem to have an affinity for fresh water, persisting in congregating in and about the open reservoirs causing more or less trouble.

The reason for the ever increasing numbers is that they are now protected by law. In the olden days, the gulls' eggs were collected and sold in the markets as food, and were used principally in the baking and confectionery trades. The gulls were also shot and used as various forms of chicken. If this condition were allowed to continue the sea gulls would have become extinct in this section. Thus with the protection that this lowly scavenger now enjoys he has become an item of importance in reservoir construction. In 1919, due to this sea gull trouble, it was found necessary to cover our Francisco Street Reservoir — and all reservoirs built since that time have been covered.

(4) The Biological Control of Impounding Reservoirs. Carl Wilson. *Jour. A.W.-W.A.*, 17: 2, 247, Feb., 1927.

Not infrequently birds assume importance on reservoirs, particularly those which send water directly into service. Swallows nesting around an outlet tower have been known to add colon bacilli to water which was otherwise perfect, thus necessitating a chlorine treatment that would not have been required. Obviously the remedy is to prevent nesting about the outlet works. In Los Angeles we have had several instances where water fowl have carried *Peridinium* from the brackish sloughs near Wilmington, or perhaps from the open sea, to our distribution reservoirs. This organism is always an unwelcome visitor in reservoirs, because it makes the water rusty red in color, and imparts a most unpleasant odor and taste when the growth finally dies.

Cormorants are also undesirable about a reservoir, first because they may seriously deplete the stock of fish, and second because of their unclean habits. Like swallows, they

haunt the outlet towers and sadly deface the structures. It has been found desirable in Los Angeles to drive them off the reservoirs by shooting.

The worst bird offenders, however, are sea gulls and mud hens. In the fall it is a common thing for 10 000 or more gulls to rest on one of our lakes at night, and the amount of guano which they deposit in the waters is sufficient to become a matter of real importance. Probably 30 grams per day per bird is a conservative estimate, and when this is multiplied by the immense numbers of birds present it is easy to see how it may affect the quality of the water. Increase in *B. coli* content is the least serious result, for chlorination may be made to remove these bacteria. The amount of oxygen consumed in the reduction of the fecal matter is great enough seriously to deplete the available reserve, and when this has been done, anaërobic bacterial activity quickly spoils the water. Moreover, the fertilizing value of the guano stimulates luxuriant growths of algæ, for these plants are quite as susceptible to the effects of fertilizers as are the farmers' crops. To be sure, growing algæ furnish free oxygen to aid in the reduction of organic pollution, but many types cannot be permitted to grow long enough to accomplish real aid in this way, for they would give rise to their peculiar bad tastes in the water. So far we have obtained our best results by shooting at the birds sufficiently to drive them from the lake.

(5) Acts and Resolves Passed by the Legislature of Massachusetts During the Session of 1924. Chapter 240.

In order to preserve the purity and prevent the pollution of the waters of Chestnut Hill and Spot Pond reservoirs, the Metropolitan District Commission may authorize one or more of its employees, so far as permissible under federal law, to take such reasonable means and use such appliances and weapons as, in the judgment of such commission, will prevent the defilement of the waters of said reservoirs by gulls or terns, any provision of Chapter 131 of the General Laws to the contrary notwithstanding. The commission shall keep an accurate account of any birds killed under the authority of this act and submit such account to the Director of the Division of Fisheries and Game of the Department of Conservation at such times and covering such periods as he may prescribe.

(6) Boating and Fishing in Ponds and Reservoirs Used as Sources of Water Supply. X. H. Goodnough. Jour. N.E.W.W.A., 34: 3, 151, Sept., 1920.

With regard to other animals, no claim has thus far been advanced that they pollute reservoirs, excepting in the case of birds, which did cause the serious pollution of Spot Pond several years ago. The source of the trouble was the gulls who in the winter or early spring would fly inland from the mud flats on the coast and settle in the waters and upon the rocks in Spot Pond. Means were quickly found, however, to prevent contamination from this cause. It should be added that the pollution chiefly feared was that carried upon the bodies of the gulls themselves, who obtain their food in part at least in the polluted waters of nearby harbors. Pollution from their excreta also is of course objectionable.

(7) Report of the Department of Food, Drugs, Water and Sewage for the Month of August, 1922. *Monthly Bulletin, Indiana State Board of Health*, 25: 8, 91, Aug., 1922.

Several laboratory analyses made of the water supply of Lafayette showed the presence of *B. coli*. An investigation indicated that pigeons which had access to the reservoir were causing the contamination. It was recommended that the reservoir at Columbia Park be tightly covered in order to exclude all birds and animals.

(8) The Covering of Open Service Reservoirs in which Filtered or Ground Waters Are Stored. G. C. Bunker and A. G. Nolte. Jour. N.E.W.W.A., 37: 3, 261, Sept., 1923.

The conditions leading up to the covering of a low-service reservoir at Panama may be of some assistance to those who are working to obtain covers for reservoirs.

Near the end of February, 1921, a vigorous growth of green filamentous algæ appeared in the reservoir. Later on the predominant organism was identified by Prof.

G. T. Moore as *Mougeotia*. From this time on we experienced continuous trouble with this organism, the growth developing to such an extent that two weeks after a cleaning of the reservoir the water would contain many long strings and floating masses, necessitating repeated cleanings at intervals of three weeks or less. Masses of the growth entered the pipes of the distribution system and decomposed, with the result that disagreeable odors and tastes were imparted to the water drawn from the taps in some of the houses. It was useless to treat one section of the reservoir at a time with copper sulphate, waste the water after standing a few days, and refill it with fresh water, because this water would have been seeded from the growth in the other section, as birds were continually skimming through the surface of the water in both sections.

Later on, the funds for covering the reservoir became available, the roof being completed in October, 1921. After the roof in each section was completed and the reservoir as a whole was thrown into service, no trouble was experienced from the multiplication of bacteria or from the development of algæ in the stored water.

When the senior author took charge of the purification of the water supplies in 1914 he anticipated that the multiplication of algæ in this reservoir would be a continuous source of trouble, but it was not until 1921 that vigorous growths of *Mougeotia* suddenly appeared and developed into a nuisance, not only to the consumers but to the maintenance force as well, on account of the frequent cleanings. If this reservoir had not been seeded with *Mougeotia*, probably by birds, it might have run on for several years without any trouble developing from multiplication of algæ.

(9) Proposed Secondary Chlorination of New York Water Supply after Leaving Open Reservoir at Hillview. W. W. Brush. *Jour. A.W.W.A.*, 14: 6, 526, Dec., 1925.

After the water passes the Kensico chlorination plant it flows through 14 miles of aqueduct. Hillview Reservoir is an open basin with a dividing wall usually below the water surface and through which a by-pass conduit is constructed which can carry about two-thirds of the present demand. From the end of August until the following April sea gulls flock to this reservoir at times numbering thousands. They alight on the water arriving about 8 o'clock and remaining until dusk. If an airplane passes over the reservoir they will disappear for the remainder of the day. Under the New York State laws they cannot be killed. For the greater part of the time from one to two men are kept out on the surface of the reservoir in a boat to shoot at the birds in such a manner as to have the shot hit the water but not hit a gull. Experience over several years has shown that the birds soon lose their fear of the men and cannot be driven away in this manner unless more boats be used. The effect of the gulls on the pollution of the supply is evident in the late summer and fall as shown by the average *B. coli* content during this season and the season when the gulls are not present. In the cold weather the effect of the gulls is not noticeable in the *B. coli* content. The water after treatment at Kensico as shown by daily tests, was free from *B. coli* in 10 cc. during the entire 12 months with the exception of one sample and was also virtually free from *B. coli* in 100 cc.

Date.	*B. coli* content in 10 cc. after the water left Hillview Reservoir.
Prior to Aug., 1924	0
Aug., 1924	0.10
Sept., 1924	1.73
Oct., 1924	0.80
Nov., 1924	0.02
Dec., 1924	0

This result was shown in spite of the by-passing of the reservoir during September and October to the extent that the capacity of the by-pass permitted.

When the Hillview chlorinating plant is installed, which it is expected will be during 1925, Hillview Reservoir effluent chlorination will counteract the gull pollution and any accidental or intentional pollution of the water while in Hillview Reservoir.

(10) The Significance of *B. coli* in Water. George Baxter. *Water and Water Engineering*, 31: 366, 262, June 20, 1929.

Experiments carried out in the laboratory of the analyst for the city of Dundee and the counties of Angus, Perth and Fife, show the extent to which the presence of *B. coli* in the water of a large reservoir may be due to a few gulls. The probability is that more or less the same results would be obtained from any aquatic bird.

From such experiments it does not seem an unreasonable assumption that on a conservative basis 100 gulls will contaminate a reservoir of 100 m.g. to the extent of giving a positive reaction for *B. coli* in 40 cc., or if the number is increased to 500, to the extent of a positive reaction in 8 cc. Obviously, on a smaller reservoir, the intensity of contamination would be proportionately increased.

(11) Twenty-third Annual Report of Metropolitan Water Board, London, for Year Ending December 31, 1928. A. Houston. (p. 90.)

Considerable prominence was given to the subject of gulls as sources of contamination of water in the writer's 17th and 18th Annual Reports, and it was further alluded to in the 19th Annual Report.

In the 18th Annual Report two striking photographs were given showing the extent of the trouble. One photograph showed 100, or more, gulls swimming about in the water on one of the filter beds at Barn Elms. The other photograph showed the gulls in flight after being startled.

On the morning of January 11, 1929, the writer was informed that the number of gulls congregating about sunset on the Barn Elms Reservoirs was phenomenal. A visit was paid to the reservoirs in the late afternoon of the same day. It was soon apparent that a vast concourse of birds had assembled on the reservoirs and their banks. Over wide stretches of the reservoirs the gulls swam close together in such countless numbers that it looked as if the water had been covered with vast blankets of snow. Finally, at a signal, some shots were fired, and in a moment the air was filled with a multitude of birds. The foreman at the works, a man of life-long experience, put the number of gulls at well over a million. Arrangements were made, then and there, for a systematic campaign (firing of guns) designed to frighten the birds away each evening, and at other periods, if necessity arose. The results proved to be most encouraging.

The water in the reservoirs was in such a bad condition bacteriologically as the result, presumably, of the gulls' visit, that on January 15 chlorination of the filtered water at Standish Road, Hammersmith, was commenced. The water before chlorination contained *B. coli* in 1 cc. After chlorination this microbe was absent from 100 cc.

The droppings of gulls contain at least one million *B. coli* per gram weight. It is difficult to arrive at the weight of filth evacuated per gull per day. In the circumstances, an appeal was made to Dr. Chalmers Mitchell, Secretary of the Zoölogical Society of London, who was kind enough to have the matter tested practically. From the results of the test it is obvious that each gull may per day contribute 50 to 100 million *B. coli* to a water works. Most of this filth will reach the water directly, or be liable to be washed in with every successive rainfall.

(12) The Isolation of *B. typhosus* from Gulls' Excreta. B. A. Adams. *The Medical Officer*, 39: 17, 185, April 28, 1928.

B. typhosus was isolated from 2 out of 96 gull droppings examined. They were isolated by means of Wilson and Blair's glucose bismuth sulphite iron medium. Organisms differing from typhoid bacilli by their cultural and other characters yielded colonies similar to that organism on this medium, but they are comparatively uncommon in gulls' excreta. These droppings were collected in the vicinity of a town in which typhoid epidemics have occurred in the past, consequently the bacillus may not be found in gull excretions where they are resident in the locality of a town in which no recent (during present generation) epidemics have occurred.

WATER-WASTE PREVENTION.

BY DAVID A. HEFFERNAN.*

[*Read September 18, 1929.*]

One of the important activities of a well-operated water department is that of waste prevention. The extreme dryness of the past summer has stressed to a number of communities the value of this phase of the water business. A recent news item stated that the water shortage has been so serious in Prussia that authorities have plugged bathtubs with lead to prevent their use. A number of municipalities in New England have enforced drastic regulations in order to conserve diminishing supplies. All this attention to careful use of water is proper, but in the normal course of events its importance will probably be dimmed soon after rains replenish the now-depleted sources.

Waste prevention is to me at all times an interesting topic, and I have often spoken on the subject before this Association. In Milton, we have been able to keep our waste at a minimum through careful management. Twenty-six years ago, with a population just half of today's and a pipe mileage which has since increased 75 per cent., our average daily per capita consumption was 44 gal., with a corresponding night flow of 15 gal. Our average to September 1, 1929 was 54 gal., with a night flow of 18 gal. Modern plumbing with its accompanying increase in water use and the current dry spell, among other things, are responsible for the increase in water consumption since 1903. At that time our water unaccounted for was about 35 per cent., while last year we were able to account for 79 per cent. of the water entering our system.

Having each service equipped with a meter is the prime requisite in accounting for water. Closely allied with it is the importance of periodic testing of meters. We plan to remove, repair and test each meter every five years. Large meters should be tested oftener. Use of water at fires, for flushing mains, and under-registration of meters, make up that part of the unaccounted-for water which is not lost by leakage. The first two are unavoidable; the latter pair may be kept at a minimum.

The larger cities are prepared to combat leakage by means of an organized corps of men whose only duty is to locate leaks in the distribution system and in services. Smaller cities and towns do not maintain a separate division, because the continued need for it is not so great. In the majority of cases the smaller municipalities employ men who are experienced in such work and who combine water-waste prevention with other water-works duties. There is also available for service to water departments an organization with special apparatus for the location of leaks.

*Superintendent of Water Works, Milton, Mass.

In all water departments, however, there is need for men and for easily portable apparatus for waste-prevention work. I have in mind leak locaters, such as aquaphones, leak detectors, geophones, etc. We have had a number of different devices and have used them with generally good success. In this connection I should like to mention a rather unusual case of leak detection.

Last winter I was called on by a citizen who was employed in a large steel warehouse in a neighboring city. He had heard of the success obtained in Milton in locating leaks and believed that we might help him with his problem.

A leak in a vacuum steam-heating system prevented proper heating of the warehouse and office, both supplied from a central heating plant. I visited the property and found that the returns were laid about a foot below a thick concrete floor and were enclosed in Akron pipe. It was necessary to check about 800 ft. of pipe. The simplest method for doing this seemed to be to lower the fires and fill the system with water and keep it under pressure. To further complicate matters, however, cranes and other machinery in the workshop and noise from machinery in near-by mills was transmitted through the ground making it impossible to do anything while the machinery was running.

The test was made on a Saturday afternoon, and we were fortunate to locate with a geophone a spot in the stock room between tiers of bins where the sound was greatest. Drilling through the floor and Akron pipe which enclosed the return, we spotted the leak within six inches. Repairs were comparatively simple.

BREAKS OF WATER MAINS, SERVICE PIPES AND HYDRANTS — A SYMPOSIUM.

[*March 12, 1930.*]

GENERAL STATEMENT.

BY FRANK A. MCINNES.*

The subject chosen for discussion provides an extremely wide field in which to wander and is chock-full of practical interest.

In order to narrow the range of my own discussion, I propose to take up water mains only, limiting myself to cast-iron pipe, drawing almost entirely upon my own experience and avoiding everything of a theoretical nature.

You will all agree with the statement that the causes of breaks in water pipes are many and varied; my job is to consider the most outstanding ones.

Rigid Bearing. Without hesitation I would class the so-called rigid bearing as the greatest offender. By the term rigid bearing is meant a point or points in a pipe line at which no settlement can take place, while adjacent pipe lengths are supported on a more or less yielding foundation. This condition may occur in a rock trench, where sufficient care has not been taken to provide a uniform cushion of good material between the top of the rock and the bottom of the pipe; with the result that a small but deadly piece of stone lies between the pipe and the rock. The same conditions may be caused by settlement upon any rigid object such as the side of a manhole, another pipe line or a foundation wall. In all cases it means certain death to the pipe in the long run.

It is necessary, if trouble is to be avoided, that the foundation of a pipe line be as uniform as possible throughout its length. If a sudden change in the character of this foundation is unavoidable, special provision must be made for supporting the pipe across the danger zone between the hard and soft supporting materials.

When pipe must be laid on a solid support such as masonry construction, a steel bridge and concrete piers, it is good practice to place wooden blocking 4 to 6 in. thick, laid on its side, directly under the pipe. Before the wood decays, the filling around the pipe will have compacted sufficiently to safely support it. In such cases, the mistake of placing the blocking on end must not be made, because wood is practically as rigid as stone in this position. This fact is well exemplified by a break which I recall in a 12-in. pipe caused by settlement on the head of a pile driven many years before the pipe was laid. In this case the ground under the pipe was good, and the opportunity for settlement on each side of the pile seemed slight. Yet the rigid bearing got in its deadly work.

*Consulting Engineer, Boston, Mass.

During subway construction in Boston, unceasing care was necessary to safeguard the water pipes, as the work was carried on continuously both day and night.

In Tremont Street, south of Boylston Street, the subway excavation extended from curb to curb, with one large main uncovered in the trench and with another lying immediately outside the sheeting on one side of the trench. It was necessary, at many points, to support the pipe on masonry piers built up from the subway, while at other points the subway structure itself was modified in order to make room for the pipes; in all such cases it was required that at least 6 in. of wood, laid on its side, be placed between the pipe and the rigid support.

Within a few months after subway construction was completed and traffic resumed on the street, several serious breaks occurred in the water pipe. Careful examination showed, in each case, that the wooden blocking had either been omitted or had been improperly placed, despite the care taken to guard against negligence of this kind. Since these breaks, no others have occurred from the same cause.

At Copley Square a 42-in. high-service main crossed the subway trench diagonally at a point where there was ample cover over the subway roof. Here a flexible pipe of the so-called "Metropolitan type" was laid and has not been heard from since.

Adjacent Excavation. Another cause for broken mains, particularly in cities and towns, is deep excavation adjacent to the pipe. This may result in settlement of the ground under the pipe or in its dangerous movement towards the excavation. Not much can be said about this particular menace, as the conditions vary widely. In good ground, where confidence can be placed in the bracing of the excavation, it is often possible to maintain the pipe in service. Under other conditions it must be shut off during construction and possibly relaid before being returned to service. Under all conditions, the sheeting and often part of the rangers and braces in the deep trench should be left in place during refilling. If the excavation is directly under the pipe and it is not possible to support it from above or by permanent means from below, a good method is to place horizontal timbers under the pipe, supporting them at each end by posts resting on a solid foundation below. In this way a uniform and somewhat yielding foundation is obtained.

Water Hammer. Water hammer must be classed as a possible enemy of water pipe, serious enough at times to bring disaster. All of us who are familiar with pressure-recording gages on a distribution system know that water hammer is always present, although rarely to a dangerous extent. It may become dangerous if a large main is carelessly or ignorantly filled and the necessary air vents are not provided or not properly operated. The care to be exercised in filling depends largely upon the profile of the line, the adequacy of the air vents and, sometimes, upon the quality of the iron in the pipe. I have had experience with a 24-in. line where the utmost care and

infinite patience were essential in filling, due entirely to the poor quality of the iron in the pipe. Any undue haste or carelessness in filling meant disaster. The chemical composition of the pipe was unusual; it had a manganese content of 1.20 per cent. The pipe was not made in this country.

I recall a break in a 12-in. pipe which had been in service without a murmur for more than 50 years. The break occurred during a fire in the vicinity of the pipe, and was caused, in all probability, by the sudden closing of one or more shut-off nozzles on the end of the hose lines. There was an original marked imperfection in the pipe at the place of fracture, but it required abnormal conditions to manifest its weakness.

I will not attempt to enumerate all the remaining causes for breaks but shall briefly consider the following: electrolysis, lightning, earthquake, frost, blasting, bad ground and the character of the pipe itself.

Electrolysis. Electrolysis is an insidious and dangerous foe and will so remain until the different agencies producing electricity succeed in keeping it under control and solely for their own use better than is now done. It is true, however, that marked progress has been made to improve the conditions.

Lightning. Lightning has been disastrous at times particularly to cement-lined pipe, although rare instances are on record in which cast-iron pipes have suffered.

Earthquakes. I am "from Missouri" in regard to damage to water mains in New England by earthquakes. Two recent breaks in large pipes in Boston have been attributed, in press notices at least, to this cause, but I am convinced, after looking into the matter, that no worth-while evidence has been adduced to justify this conclusion. Everybody knows that an earthquake shock can, and does in other parts of the world, break cast-iron mains like eggshells. In New England we have not, since water distribution systems were first laid, experienced quakes of the water-main-breaking class. Whether leaks may have resulted from this cause is perhaps open to question.

Frost. The effects of frost are well known. I shall only mention one somewhat unusual example of its effect. A 12-in. pipe was supported on piers built up from the haunches of a large sewer with little or no blocking under the pipe. The ground froze solidly from the surface to a point below the top of the pipe, and its expansion caused the pipe to break at several points over the piers.

Blasting. There is not much to be said about blasting as the cause of pipe failure, for the effect is usually plainly apparent. It is possible, however, to do remarkable work in safely excavating ledge rock under a water pipe by intelligent location of the drill holes and by the use of small charges of powder.

Bad Ground. We are all familiar with bad ground as an enemy, and we know the manner in which it changes cast iron into a material that can be readily cut with a knife. The evil results usually occur in salt marshland

or in land that has been reclaimed from the sea without sufficient attention to the character of the fill.

Character of Pipe. The last cause mentioned, namely, the character of the pipe itself, is undoubtedly to blame for some breaks which take joy out of the life of the water-works man. The defect and consequent weakness in the pipe may be inherent in the quality of the iron, or it may be due to improper foundry practice resulting in uneven pipe, cold shuts, sand or dirt holes, gas holes, etc.

It was our practice in Boston to have a chemical analysis made of the iron in the pipe when a break occurred; this method pointed straight to the cause of the trouble in the following cases:

A large main, laid in 1869, operating under approximately 20-lb. per sq. in. pressure, broke at several points when the pressure was increased by 7 lb. The chemical analysis showed in each case an abnormally high silicon content with the combined carbon dangerously low as would be expected under such conditions.

Two 12-in. and an 8-in. pipe broke in which both the combined carbon and the sulphur content were altogether too high for safety.

One 12-in. and one 10-in. pipe broke in which the sulphur content was distinctly dangerous.

Two 12-in. pipes failed in which the combined carbon content was high enough to surely make the pipe abnormally brittle.

It is only fair to say that the breaks just mentioned all took place in pipe cast at least 20 years ago. Since that time, notable improvement has been made in foundry methods. It is now an accepted practice at the pipe foundries to safeguard the quality of the metal by making daily analyses and by breaking test bars poured from the iron which goes into the pipe.

Damage During Transportation. There is still another case of weakness in the pipe itself which is particularly annoying. I refer to damage received in transit between foundry and destination. It occurs in both rail and water delivery and usually manifests itself in cracks at the spigot ends. These, fortunately, can be detected in most cases by expert inspection. When the cracks are very small, particularly when they are in the body of the pipe, they may escape detection, and a break will almost surely result when the pipe is tested or put in service.

It is true that water pipe sometimes experiences very rough usage on its trips from the foundry, but it is also true that proper care is not always taken in loading it at the foundry.

Conclusion. To conclude with a few words of a more personal nature: Good fellowship has always been one of our notable assets. But our Constitution, Art. 1, Sec. 2, specifies more than this pleasant feature. It also asks for "the advancement of knowledge relating to water works and water supply." In this respect there is still room for improvement. We do not always realize that each of us has something to give which is of value to the other fellow, which his experience has never given him an opportunity to

learn, and which is of decided interest to him. The common mistake made is that the information or experience in question seems of little importance, as it is an everyday happening. I shall illustrate this point as follows.

A number of years ago the Civil Service Commission suddenly discovered that six of the best foremen in the Boston Water Department would have to pass a written examination or give up their jobs. An oral examination was finally decided upon. One of the men, a particularly capable one, was so nervous that it was necessary to appoint a fellow workman to see that he presented himself at the State House on time. When the examination was over, I asked the nervous man how he got along. His answer was, "Sure it was the damn fool questions they asked me." I then wanted to know what the questions were. He said they had asked him how long it would take him to cut a 20-in. and a 6-in. pipe on the street, what tools he would need, how many men he would want and what each man would have to do; also how much lead and yarn he would need for each pipe. The man simply did not realize that his experience alone made the questions given him seem easy and that they would have been really difficult for one without that experience.

EXPERIENCE IN METROPOLITAN BOSTON.

BY SAMUEL E. KILLAM.*

It is the writer's purpose to supplement his paper on "Breaks in Water Mains" read before this Association on September 14, 1916.

The Metropolitan system supplies water to the Boston Metropolitan District through 154 miles of pipe varying from 60 to 10 in. in diameter, 135 miles being of cast iron.

There have been 46 breaks in the system since January 1, 1898, when the Metropolitan Commission took over the operation and maintenance of the supply works. Twelve of these breaks occurred in pipes in existing local systems that were taken over as part of the supply works.

The following schedule gives the list of breaks that have occurred from 1917 to 1929, inclusive:

Date of Break.	Diam. of Pipe. In.	Location.	Reported Cause of Break.
Feb. 14, 1917	30	Boylston St., near Cypress St., Brookline.	Settlement on brick piers.
Jun. 7, 1918	12	Atlantic Ave., Revere.	Electrolysis.
Sep. 15, 1918	30	Cross St., near Main St., Malden.	Cause unknown.
May 29, 1919	16	Beach St., Revere.	Cracked pipe.
Apr. 17, 1920	48	Clinton Rd., Brookline.	Cracked pipe.
Jan. 7, 1921	36	Fellsway East, Malden.	Cause unknown.
Mar. 19, 1923	48	Beacon St., at Fairbanks St., Brookline.	Cause unknown.
Feb. 5, 1925	4	Pines River, Lynn.	Blow-off for 16-in. main frozen.
Jun. 7, 1925	12	Atlantic Ave., Revere.	Electrolysis.
Nov. 18, 1925	12	Washington St., Lynn.	Cause unknown.
Jan. 6, 1926	12	Washington St., Lynn.	Electrolysis.
Jan. 17, 1926	36	Morton St., West Roxbury.	Blasting by contractor.
Apr. 20, 1926	36	Fells Reservation, Malden.	Blasting by contractor.
Apr. 21, 1926	6	Mystic Shops, Somerville.	Settlement on rock.
Sep. 20, 1926	48	Commonwealth Ave., at Auburn St., Newton.	Settlement on rock.
Jul. 21, 1927	36	Morton St., Dorchester.	Blasting by contractor.
Jan. 6, 1928	48	Clinton Rd., Brookline.	Cracked pipe.
Apr. 11, 1928	60	Near Wright's Pond, Medford.	Large boulder rolled onto main by contractor.
Feb. 9, 1929	8	Pumping Station Grounds, Brighton.	Settlement on rock.
Oct. 10, 1929	20	Mystic River, Medford.	Settlement in river.
Dec. 14, 1929	48	Clinton Rd., Brookline.	Cause unknown.

It is the writer's opinion that some of these breaks were caused indirectly by heavy street traffic. Electric cars and heavily laden trucks passing over a modern street surface cause a tremor under the surface which is transmitted to the pipe line. This constant vibration disturbs the material around the pipe, permitting settlement of the pipe line, perhaps causing a leak in a joint or possibly a crack in a pipe.

*Superintendent, Distribution Section, Water Division, Metropolitan District Commission, Boston, Mass.

The water released from a pipe line under a modern street surface finds an outlet some distance from the leak, and the material may be washed away from under the pipe and permit the pipe line to settle onto a rigid support.

The schedule shows four breaks caused directly by contractors. Three of these were probably due to careless or excessive use of explosives and the fourth to carelessness. In the three in which the contractors were using explosives, trenches were being excavated parallel to and in close proximity to the Metropolitan main. The fourth break, caused by carelessness, was due to a contractor rolling a large boulder weighing about twenty tons down an embankment and onto a 60-in. main. The break in the 20-in. main crossing under the Mystic River between Medford and Somerville was caused by settlement of the pipe in the river bed. Some difficulty had been experienced in holding the pipe in line on the Medford shore, and it had been securely anchored with concrete. The line crossing under the river was made up of 12-ft. sections with spherical joints, and it is evident that there was some settlement in this pipe line. The weight of the pipe, water and the material on the pipe caused a rupture of one of the bells of one of the spherical joints.

As mentioned in my previous paper, there had been 13 breaks up to 1916 on the 48-in. main which was laid through Brookline in 1869 by the city of Boston and acquired as a part of the Metropolitan system in 1913. Since 1916 there have been three additional ruptures, but only one of these was a complete fracture. This occurred on December 14, 1929, when an emergency call notified us of a bad leak. When a report is received of trouble on this line, the first operation is to close off the line before examining the location of the leak. From eyewitnesses it is evident that the complete fracture came a few minutes before the line was completely closed. No property damage was caused by this break because of the promptness in closing the line. About the time the complete rupture occurred in this line, but probably a few minutes before, the 30-in. low-service main in Huntington Avenue, Boston, broke, causing considerable damage and wasting over 4 m.g. of water. This break in Boston was at the same time as the one on the Metropolitan in Brookline, but no cause has been found for either break. It is evident, however, that the bell of the Metropolitan main had been cracked for some time. A slight water hammer may have caused the rupture, but there was no indication on the recording gages of any serious disturbance in the hydraulic grade.

Engineers and superintendents having responsible charge of water supplies, especially in thickly populated districts, should be prepared to meet any emergency which may arise, for the general public has but little thought for an efficient water-works official, but is quick to censure him when anything goes wrong. Breaks, or the possibility of a break, in water mains will continue to be the water-works official's nightmare.

EXPERIENCE IN NEW BEDFORD.

BY STEPHEN H. TAYLOR.*

Cement-lined Pipes. The New Bedford Water System was first put into service in 1869 and contained about 9½ miles of wrought-iron, cement-lined pipe. Our report for 1877, when there were about 28 miles of cast-iron and 9½ miles of wrought-iron, cement-lined pipe, has the following to say on the subject of cement-lined mains:

The superintendent of the Binghamton Water Works in his annual report for 1876 says: "Street mains are in bad condition on account of the sheet iron rusting. As soon as the iron is eaten away by rust so as to lose its strength, it breaks out. I think there should be no delay in purchasing cast-iron pipe and put in place of the cement pipe in the streets of the city." Of 46 leaks mentioned in the same report 32 of them were due to deterioration of the sheet iron. The Water Report of New Britain, Conn., for the same year cites in this connection: "The general repairs have cost less than for several years past which result may be attributed to some extent to the large amount of cast-iron pipe, with which it has become necessary to replace the old cement-lined mains. Repairs on the latter always cost more and are of more frequent occurrence." The cement-lined pipes in New Bedford have been in use about 8 years, and as yet it has not been necessary to take up any appreciable length on account of deterioration. In most cases where cement-lined mains have been tapped for service the removal of the outside coat of cement has shown the iron bright as when laid.

The favorable experience at New Bedford was, undoubtedly, due to the care with which the mains were laid. For several years following this, the reports contain mention of numerous cases where holes were made in these cement-lined pipes by workmen, mostly from other departments, using picks or other tools in laying sewers, drains, etc. There were a number of these every year.

In 1880, the superintendent in his report states that the cement-lined pipes are in precarious condition and recommends replacing them with cast iron. The reports for succeeding years show that the cement-lined pipe was gradually removed, until in 1898 the last of it was out. This was the year previous to turning on the increased pressure from the new reservoir at a higher elevation than the old one. This, of course, ended our troubles with cement-lined pipe.

Fish Island Supply. In 1880 about 400 ft. of 2-in. lead pipe were laid in the bottom of the river to supply Fish Island. The pipe was simply dropped on the river bed and was not covered. This pipe was the source of considerable trouble due to freezing by anchor ice in the river and to being picked up by anchors dragged by boats in their passage through the draw. The trouble experienced with this lead pipe increased until 1898, when it was removed and replaced by 6-in. Ward flexible-jointed pipe.

*Superintendent of Water Works, New Bedford, Mass.

This pipe, like the lead pipe, was not properly covered, and during the following year (1899), it was irreparably damaged by dredging operations, a section of the pipe being broken by a heavy stone dropped overboard from the scow. In 1904, another 6-in. flexible-jointed pipe was laid under the draw. This pipe continued in service until 1915, when it was removed by order of the federal government on account of dredging operations in the channel. For some years after this, the only supply to the island was through a 2-in. pipe laid on top of the bridge. This pipe was disconnected at the draw during the daytime and connected up and used during the night, when the draw was not in operation, to fill a tank on the island. This system supplied the island until 1921, when another attempt was made to maintain a 2-in. lead pipe on the river bottom. The attempt was unsuccessful, however, principally on account of freezing during the winter, as the pipe was not buried. Considerable difficulty from leaks was experienced with all these attempts in supplying the island. In 1924 another 6-in. cast-iron main with a few flexible joints was laid in a trench dredged 4 ft. below the river bottom and back-filled to the original level of the bottom. Very little trouble has been experienced since this line was installed. This seems to prove that the only proper way to maintain a line under a river is to have it covered in the same way as lines laid in streets or elsewhere.

Electrolysis. We have had a few breaks which could be definitely traced to electrolytic action caused by current escaping from the Union Street Railway system. Twice within the past twenty years, we have had a systematic electrolysis examination made by William E. Foss in the joint interests of ourselves, the Union Street Railway Company, the New Bedford Gas & Edison Light Company and the New England Telephone & Telegraph Company. The town of Dartmouth was also interested in the last inspection by Mr. Foss which was made in 1928. The same interests have recently made arrangements for quarterly inspections of the more important points by the engineers of the New England Telephone & Telegraph Company. So far as I know, this is the first time that all the various interests have got together for periodical inspections, and I believe it would be well worth while if this were done more generally.

As a result of recommendations by Mr. Foss, we have installed near the power station a permanent connection between the underground structures of the various interests and the negative bus bar in the station, for the purpose of creating a proper channel for the stray current to return to the power station. At several other points where considerable stray current was found leaving the mains, it has been conducted to the river by means of wires and metallic plates below water. In our city the course of this stray current is usually over the mains to the river, thence by the river to the power station which is located on the river bank. As a result of these inspections, the Union Street Railway Company has improved the conditions within its own system, and so have all the other interests involved. We feel

that we have taken pretty good care of the situation so far as electrolysis is concerned.

Cast-iron Mains. The analysis of leaks in cast-iron mains for the past 52 years shows that the number of leaks per year has varied from 27 to 6, with an average of 13.2 leaks per year; the greatest number being in the first few years after the pressure was increased by the new system. The maximum number of leaks per mile has varied from .39 to .04 with an average of .11. In 1929 the leaks averaged 1 to every 223 inch-miles. Of the total number of leaks previously mentioned (13.2 per year), 10.7 were due to defective joints and 2.5 were due to cracks or breaks in pipes and castings in an average length of 115 miles of pipe. While some of the larger breaks make a deep and lasting impression on our minds, it must be admitted, when we come to analyze these facts, that the number of leaks due to defective pipes and castings per year per mile of pipe is rather small.

Steel Mains. We have a line of 48-in. steel main $\frac{5}{16}$ in. thick which was put in service in 1899. While we have had no trouble from leaks in this line, examination of the line in recent years show that the line is pretty badly pitted and that it will begin to give serious trouble before many more years elapse. Many of the pits extend more than halfway through the shell; others are of larger area but not so deep.

Leaks. It may be of interest to cite a few of the outstanding leaks that have occurred in New Bedford in the memory of the writer.

On April 5, 1901, a 36-in. main that had been laid two years previously burst. A large piece, oval in shape, about 3 ft. wide and 5 ft. long, blew out of the middle of the pipe. The break extended from the bottom upwards on the side. There were no cracks in the remaining section or spigot end, and no apparent cause for the break could be found. The iron was apparently of full thickness and of good quality and had been tested under 300 lb. per sq. in. pressure. The pressure under which it broke was about 50 lb. per sq. in., and there was apparently no water hammer.

A singular leak occurred on November 24, 1907. Early in the day, water was reported issuing from the ground at Wamsutta Street and Acushnet Avenue. It developed that the water came from a leak in the gas main. It was puzzling to locate the source of the water. At first, it was suspected that a gas pipe, laid beneath a brook nearby, had allowed water to enter, but an examination failed to disclose any leak there. Later in the day, attention was called to a humming noise at Purchase and Clark streets, six blocks from where the water appeared from the gas main. There were no surface indications of a leak at this point. Near this place, the gas pipe crossed just beneath a branch pipe which supplied a hydrant, the pipes being only about $\frac{1}{2}$ in. apart. A hole of large size had been made through both pipes, and so tight was the connection between the two pipes that when the trench was opened below the lowest pipe (gas) and within one foot of the holes, no water appeared in the trench. The whole neighborhood was being served with water through the gas fixtures. It was practically as if the two pipes had been connected by a nipple. No cause was ever determined. The holes had the appearance of being melted out quickly. There were several pits in the iron which had the same appearance. The iron of both castings appeared to be excellent.

On Sunday, January 6, 1924, at 8.45 A.M. an unusual drop in pressure was noted by the watchman at the Purchase Street Station. The chief engineer and superintendent were promptly notified, and an investigation proved the cause to be a serious break in one of the 36-in. mains in the private way near High Hill Reservoir. A piece of iron about half the length and about one-third the circumference of the pipe had blown out just back of the bell, and a crack extended the entire length of the bottom of the 12-ft. pipe. A considerable area of the fill over the pipe was washed away, and the escaping water scoured a hole about 12 ft. deep under the break. During the five hours between the time the break occurred and the time that the section of the main was shut off, about 14 m.g. of water escaped. Repairs were completed on January 9, and water turned into the pipe on the next day. This pipe was made in 1909 under careful inspection and test. It was laid in 1910, and has been in service ever since. It was .90 in. thick and served under about 30 lb. per sq. in. pressure. The cause of the break is difficult of determination. There was no evidence of settling, and the main was located in a place where no traffic passes over it. As nearly as can be determined from careful examination by several experts and by chemical analysis and photomicrographs, it seems likely that the crack started in the spigot end and extended toward the bell, causing a rupture from about the middle to the bell end.

On Friday, June 24, 1927, a leak occurred on the 8-in. main in Harbor Street, south of Gifford Street. The night consumption, figured at 6 A.M. on that day, indicated an increase of about 1 m.g. above the average. Low pressure was noted at the Hathaway Mill soon after midnight. There was no evidence of water on the surface, but sewer manholes in the Hathaway Mill yard were overflowing. The leak was finally found inside a sewer manhole which had been built around our main. A piece of pipe about 20 in. long and 6 in. wide had blown out of the pipe, and the water was escaping through the sewer. The manhole in which the water appeared was about 100 ft. from the break. This made it extremely difficult to locate the break, but by observing the loss in pressure at various hydrants in the vicinity, we were able to locate it within about 15 ft. before breaking into the street. The break was probably caused by electrolysis, as any current which might be following the pipe would be likely to leave it at this point and follow the water in the sewer to the river and thence to its source at the street railway power station. The water pipe was raised so that it now passes over the sewer, and it is hoped that this will prevent any future recurrence of the trouble. The cost of the leak and repairs was $264.22.

A very unusual break in a water main occurred on Sunday, September 11, 1927 at New Bedford, Mass., during an electrical storm at about noon, when lightning struck an 8-in. DeLavaud centrifugally-cast main in service on Felton Street between Tarkiln Hill Road and Holden Street. This is a sparsely built-up section of the city, and the pipe was laid in the spring of 1927 to furnish fire protection for the new Junior High School. A bolt of lightning was seen to enter the ground, followed immediately by a gush of water from the spot where it entered. Word was sent to the water-works shop, and the water was shut off. On excavating, it was found that one 12-ft. length of 8-in. pipe was cracked along its entire length on the easterly side of the pipe. The street pavement over the break appeared as if an explosion had occurred underground, causing a violent upheaval of the earth. There were no poles or trees near the place where the break occurred, and thus there was apparently nothing which would account for drawing the bolt to that particular spot. The nearest post hydrant was

50 ft. away from the break and bore no evidence of having been affected. The nearest gate box was 100 ft. away and likewise showed no signs of disturbance. In fact, the iron cover was buried a few inches under the street surface. There were no house services near the point where the break occurred. The pipe was buried 4 ft., and joints were made with Leadite. The soil was hard pan with no unusual features, and the street was paved with tar-bound macadam. Hence, no reason can be found for this occurrence except that lightning does strange things. About 1 m.g. of water were lost through this break.

EXPERIENCE AT QUINCY AND REVERE.

BY FRANK A. MARSTON.*

In the years 1926 and 1927, extensive improvements were made to the water-works distribution systems in the cities of Quincy and Revere, Mass.

Sand-cast and Centrifugally-cast Pipe. Some of the cast-iron pipe used in this work was the ordinary sand-cast pipe, but much of it was centrifugally-cast pipe. The pipe was tested in the usual manner under a hydrostatic pressure of 300 lb. per sq. in. at the foundry and was also inspected at the foundry by a commercial inspection service before being shipped. The pipe was again inspected upon removal from the cars and again at the trench before laying. After completion, all sections of the mains were tested under water pressures 50 per cent. greater than the static pressures that prevailed in the various locations.

Over 3 miles of 12- and 20-in. sand-cast pipe were laid in these two cities during the same period that 15 miles of centrifugally-cast pipe 8 to 16 in. in size were laid.

With similar conditions of laying and of service, there were no unexplained breaks in the sand-cast pipe, as compared with 12 unexplained breaks in the centrifugally-cast pipe. By unexplained breaks is meant breaks which occurred under water pressure, the cause not being apparent.

In general, the breaks were more or less similar in appearance. As a rule, a longitudinal section blew out from the middle of the pipe, but in some cases the break continued either through the bell or the spigot end. One end of the break usually had a spiral direction, and the section of the broken pipe had a conchoidal fracture, such as is found when a piece of thick glass is broken. The fractures, when examined promptly, showed bright new metal of excellent quality throughout. In a few instances only, there was a small difference in the thickness of the metal on opposite sides of the pipe.

Pieces of metal from several of the broken pipes were sent to the foundry for examination, but in no instance was anything detected that would indicate an inferior quality of metal. One piece of pipe was subjected to X-ray examination, and photographs were made, but this analysis did not reveal any specific reason for the break.

In all, 9 breaks occurred in the city of Quincy due to causes which could not be definitely determined. In general, the damage caused was slight, but in two cases, because of the location of the break, the damage was considerable. While these breaks were at times very annoying, they did not prove of much economic significance.

If all the cast-iron pipe laid in the city of Quincy during the period referred to had been of the ordinary sand-cast type, the cost of the pipe alone based on alternate bids received would have been $8 400 greater than

*Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

for the centrifugally-cast pipe actually used. The total cost incurred to the city because of these breaks has amounted to $2 100, leaving a substantial balance to the credit of the centrifugally-cast pipe.

A careful study of these breaks has led to the belief that the breaks have been due to the somewhat greater brittleness of the centrifugal pipe as compared with the ordinary sand-cast pipe and the probability that at some time after leaving the foundry the pipe received a sharp blow which caused an incipient crack in the middle of the barrel of the pipe, a crack so small that it could not be detected by the usual means of test available in the field. This incipient crack, under the strain of water pressure, gradually became larger and was finally the cause of the blowing out of a section of the barrel of the pipe.

There are a number of factors that lend support to this conclusion. The visible breakage in a car of centrifugal pipe seemed to be greater than in corresponding carloads of sand-cast pipe packed with the same degree of care. At Quincy, a number of carloads of pipe came to the destination without the usual hay-rope wrappings around the spigot ends of the pipe, and with insufficient timber braces to prevent the pipe from being knocked about in the gondola cars. When this condition was called to the attention of the foundry, the trouble was remedied, and thereafter there was less breakage during shipment. The pipe, although unloaded from the cars and stacked in the store-yard by city forces accustomed to this work, was hauled and distributed along the trench by truckmen employed by the pipe-laying contractors. In spite of attempts to prevent abuse of the pipe, it is possible that there were instances in which the pipe was handled in a rougher manner than would have been the case if the city water-works men had distributed the pipe. On the other hand, it is evident that some care was used in handling and inspecting the pipe, from the fact that no spigot-end cracks were discovered when the pipe was laid and put under test pressure.

Up to 1926, the manufacturers had not had so much experience in the making of this kind of pipe as they have had since, and it is possible that there may have been some fault in the annealing process which caused stresses to be left in the pipe, constituting a weakness which later on caused a break in the pipe.

As a result of these experiences, a careful investigation was made of the results obtained during use of centrifugal pipe in a number of other water works. In a total of 891 000 linear feet (169 miles) of centrifugally-cast pipe laid, there were 52 breaks due to causes unexplained. In a number of places there had been no such breaks, while in other places there had been several.

Of the breaks tabulated, 40 per cent. occurred when the initial water pressure was applied; 21 per cent. within one month after laying the pipe; 15 per cent. between the first and sixth month; 9 per cent. between the sixth and twelfth month; 4 per cent. in the second year and 11 per cent. after two years of service.

In the case of breaks which occurred after two years of service, it is quite possible that the break was caused by some condition not inherent in the new pipe.

On the basis of cost only, the use of centrifugally-cast pipe has been justified in each of the places investigated. In no case has the cost of the breaks been sufficient to offset the saving effected by the purchase of centrifugally-cast pipe over the cost that would have been incurred had ordinary sand-cast pipe been purchased, based on the prices actually bid.

It is to the credit of the foundry to state that every effort has been made to determine the cause of these unexplained breaks and to find a means for preventing them.

These experiences point to the necessity of greater care in shipping and handling cast-iron pipe having thin walls and greater brittleness, also to the necessity for careful inspection and tests, if the advantages to be obtained from the use of such pipe are to be enjoyed to the fullest degree.

Pipes in Peat Bogs. Other interesting breaks have occurred where cast-iron pipe has been laid through peat bogs adjacent to salt water. In one case to which the writer has reference, the peat, or salt marshes, are located close to high-tide level so that open pipe trenches fill and empty with the tide. The pipe was tar coated and was laid in the trench without special supports or special protection of the iron. A piece of pipe, removed after 9 years of exposure to salt marsh conditions, was found to have a heavy coat of peat adhering to much of the exterior surface. This coating could be pried off with a knife, had a thickness varying from $\frac{1}{16}$ to $\frac{1}{8}$ in., was black in color, had a strong tar-like odor and was hard and brittle. The surface of the coating or scale in contact with the pipe was discolored in spots with iron rust, giving it a speckled brown appearance. This scale-like coating was quite hard and brittle. The surface of the pipe had traces of tar coating, but for the most part the tar coating appeared to have been destroyed or absorbed by the peat. The iron of the pipe was rusted in spots and softened so that cone-like craters could be cut out of the iron with a jackknife, the iron having a consistency like that of hard graphite in a lead pencil. The appearance of the exterior of the pipe was much like that encountered when pipe has been pitted by electrolysis.

A somewhat similar experience was had with uncoated cast-iron gas pipe, but after a period of 10 to 15 years the corrosion of the iron had not gone far enough to make it necessary to relay any of the pipe.

Since 1909, 29 such breaks have occurred along the water-front at points for the most part not over 500 ft. from the shore line. At one point, 7 breaks have occurred in a period of 19 years. At another point, 500 ft. from the first, 6 breaks have occurred in 11 years. In some cases, the pipe has been replaced by new pipe laid with a depth of cover of only 2 ft. and surrounded with screened gravel to keep the peat from coming in contact with the pipe.

It is possible that the trouble may be due to electrolysis, although no actual measurements have been made that would prove this to be so.

The presence of salt water apparently increases corrosion but the trouble only occurs where peat is in contact with the cast iron. In sand and gravel close to the salt water, the same action does not seem to take place.

Another break, of a type not commonly seen, occurred in a 20-in. Class C, sand-cast pipe due to the wearing away of the shell of the pipe to paper thinness by a small jet of water issuing from a crack in a Leadite joint and striking against the barrel of the pipe. At the time the pipe was laid and tested, there was no noticeable crack in the joint or excess leakage of water in the section. The wearing away of the pipe wall with an original thickness of $\frac{9}{10}$ in. occurred within $2\frac{1}{2}$ years after the pipe was put into service.

A CLASSIFICATION OF MAJOR INTERRUPTIONS.

BY CHARLES W. MOWRY.*

We have recently made an analysis of 405 major interruptions of public water supplies in different parts of the United States and Canada. In all cases, an entire community, or a considerable portion of it, was without water supply for from ten hours to two or three days. Thirty-seven of the failures, or 9 per cent., were at the source of supply,— that is, either at the reservoir or the standpipe. They were due to the following causes:

Drought	20
Failure of dam	7
Anchor ice	4
Miscellaneous	6

Hence 24 of these interruptions were caused by the elements.

The next major trouble was at the pumping station. Interruption of service at this point accounts for 135 of the failures, or 33 per cent., distributed as follows:

Failure of electric power	45
High water and floods	20
Mechanical trouble at pump	20
Anchor and needle ice	20
Damage to station by fire	5
Damage to station by windstorm	4
Inadequate wells	5
Broken mains at pumps	5
Electric motor trouble	3
Obstruction in pump suction	3
Inadequate pumping capacity	2
New construction	3

Forty-nine of the failures were caused by the elements.

In the distribution system, there occurred 233 failures, or more than half of the total. Breaks in mains resulted from the various causes that have been mentioned by others, such as failure of lead joints, explosion or blasting, split pipes, excess pressures, floods, collapse of bridges, electrolysis and frost. There were 183 in this group. There were also 10 failures due to defective valves.

Mr. Killam has stated that the interruption of service is the nightmare of the practical water-works man. It is also the nightmare of the fire-protection engineer, since an entire city, or a large part of it, may be entirely without fire protection until service is restored.

At Hamilton, Ohio, a number of years ago, floods placed the water-works system out of operation. At the same time, the rising waters caused some lime to ignite at the Champion Coated Paper Company. Fortunately a secondary supply from the fire pump of the company was available to first put out the fire and next to supply the town with water for a number of days until service was restored.

*Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

SERVICE PIPES.

BY GEORGE H. FINNERAN.*

If the story of a service pipe ended when the pipe was laid, water-works men would escape a lot of work and worry. There may be cities and towns in which the pipes are laid by private plumbers and maintained by the consumers, but such places are in the minority.

The city I represent lays and maintains the pipes from the main to property line. Services for domestic use from which a revenue is derived are maintained without expense to the consumer. Services for fire protection, from which nothing but a service charge of $10 is collected, are maintained at the expense of the owner. This is true also for services furnishing motive power to elevators and organs.

For a ¾-in. domestic supply pipe, the applicant is charged a flat price of $55. For sizes above that, he must pay actual cost plus ten per cent. to cover overhead.

Pipes ⅝, ¾, and 1 in. in diameter are laid with corporation and curb cocks. The curb cocks have boxes accessible at the surface, through which the cocks below can be operated. The corporation cocks also have boxes, some of which rise to a point about 18 in. below the surface, while others come to the surface. The purpose of the corporation boxes is to enable us to use a long rod or wrench on the corporation cock with little or no digging in the street. The cocks, of course, have to be set horizontally in the main pipe.

Pipes 1¼, 1½, and 2 in. in diameter are laid without curb cocks, but have corporation boxes that extend to the surface and afford a means of control. As our pipes 2 in. or less in diameter are almost all made of lead, curb cocks 1¼, 1½, and 2 in. in size are not considered to be practical. The plugs in cocks of that size turn with too much resistance, and as the lead pipe on either side of the cock is not sufficiently rigid, the force required to operate the cock will bend the lead pipe. Pipes more than 2 in. in diameter are equipped with gates.

There are about 122 000 service pipes with a total length of about 628 miles in the city of Boston. Our attention, which in most cases involves work and expense of a greater or less amount, is required by service pipes for the following reasons:

Leaks.
Stoppages.
Frozen water.
Settlement of trench back fill.
Corporation cocks broken.
Curb cocks out of position to engage wrench.
Corporation and curb boxes — too high — too low — broken — filled with dirt — filled with concrete — parts missing — in way of edgestone — covered by artificial stone sidewalk or asphalt roadway.

*Superintendent of Water Service, Boston, Mass.

Pipes in way of new underground structures.
Trouble on private property requiring shutting off and turning on.
Abandoned pipes, and other causes.

By far the most numerous and most serious of these causes are leaks and stoppages. Leaks are caused largely by settlement of the ground in which the pipe is laid. Sometimes it is the back-fill on top of the pipe; at other times it is the ground under the pipe. In either case the pipe is dragged down, strained and stretched until a cleavage or opening develops immediately back of the tailpiece of the coupling, or where the brass and solder end and the lead begins. The variation in the tensile strength of the two materials causes the break. In the case of cast-iron services, rigid bearing combined with settlement causes the break.

Other causes of leaks are: pipes corroded by electrolysis, ashes and salt-marsh soil; loose couplings; worn packings; water hammer; foundation walls eaten by rats; and struck by pick.

Of this variety of causes, I think electrolytic corrosion and water hammer are the most interesting as they represent the practical consequences of present-day domestic conveniences.

Electrolysis. Electrolysis of water pipes came in with the electric car, and for a long time any breakdown in the structure of iron or lead pipes was charged to stray return-currents of electric street railways. It was considered to be almost impossible for electrolysis in a water pipe to be caused by current from an electric lighting system. While many service pipes are still being damaged by street railway current, we are experiencing an increasing number of cases in which leaky lighting circuits are the causative agents.

When the electric lighting companies first installed underground services to buildings, a wire of capacity adequate for the demand of that time, insulated with a thick covering of rubber and cotton composition, was laid in the ground without any further protection than a wooden plank 4 to 6 in. wide placed over the wire, presumably to protect it from picks and crowbars in the hands of diggers.

As time went on, the insulation deteriorated due to the action of the soil and to the heat associated in the overloading of wires carrying an increased flow of current. The latter was due to the many new uses to which electricity was put. With the insulation gone, the current got into the ground, thence onto pipes and thence off again with the inevitable electrolysis caused when current leaves pipe for another path. In some cases, so much current is astray that when the hand is accidentally placed against the side of a trench a decided shock is felt. Recently we have had cases where pipes have been renewed only to be again attacked within a short time and again renewed and again destroyed. When finally the electric lighting company made a survey of the troublesome areas, the trouble was located and remedied and the destruction of our pipes stopped.

It would be interesting to know just how much damage, if any, is caused by the grounding of electric lighting and radio wires on water pipes.

While it has been understood that nothing serious results from the grounding of electric lighting circuits on a water pipe, it would make one feel better to know just how much current flows onto pipes from these ground wires and what happens to the pipes when the current leaves, as it must, somewhere to go into the ground.

Water Hammer. The other cause of leaks, which is of interest at the present time, is water hammer caused by the operation of quick-closing faucets, flushometers, etc. We are having considerable trouble with lead services — 2 in. in diameter — carrying pressures of 75 to 90 lb. per sq. in. and entering buildings containing offices and apartments with plumbing fixtures of the latest type. The lead pipe swells or balloons at a point usually nearer the building than the main and finally splits or bursts. The pipe is repaired, and later it bursts again in the same way, perhaps not in the same place, but close to it. It is singular that this type of leak seems to be confined almost entirely to lead pipes of 2-in. diameter. We very seldom have 1½-in. pipes burst in that way. There must be a relation between the area of the pipe, the thickness of its walls, the normal pressure and that due to water hammer.

Because of this trouble, we have changed from lead as a material for 2-in. service pipes to heavy red brass and recently to copper tubing, with the expectation that it will withstand water hammer as well as corrosion, both internal and external.

With reference to the use of copper tubing, the only hesitancy we had in placing it in the ground was due to anxiety as to how it would act if struck by a pick or crowbar. The consequences of a pick hole in a copper tube, ¾ or 1 in. in diameter, are not so serious as for 2-in. pipe. Furthermore, the larger pipe is more easily hit by a pick; it offers more of a target. With the increasing amount of underground work carried on by utility companies we felt that some protection should be given the 2-in. copper pipe. We have therefore prescribed the use, in its installation, of a 2-in. plank laid over the pipe to intercept the pick or bar as it is sunk into the ground.

Another trouble that we find to be increasing is the damage done to corporation boxes by steam shovels and steam rollers. I do not think that other cities and towns suffer to any great extent from this trouble, because outside of Boston and Worcester, I do not know of any places where corporation boxes are used. It is the price we pay for their convenience.

In the case of gate boxes, used everywhere, steam shovels will dig them up or displace them, and steam rollers will crush or bury them. The increasing amount of street construction and the increasing use of machinery in the work makes the conservation of our fixtures an important problem.

As stated before, one of the common causes for work on service pipes is trouble on private property that calls for shutting off and turning on water. Ordinarily, this is a service supplied by the water department to the consumer to facilitate plumbing work of such a nature as to require shutting off the water at the sidewalk. Sometimes this service is given free,

sometimes for a price; in Boston it is free. We are called many times to shut off water where we find the pipes in cellars burst or broken, usually at the wall on our side of the cellar stop cock, but quite often on the consumer's side, where it could be controlled by occupant or owner. The occupant or owner will not attempt to do anything; he depends on us. Cases of this kind occur more frequently in the poorer sections where there are several tenants in a house and the landlord is an absentee. The tenants do not know and do not care about shutting off the water in the cellar; we have to attend to the matter. Sometimes our men go into the cellar and shut the stop cock, when they should shut off the water at the curb cock. The latter would save us from possible litigation, growing out of a broken stop cock in the cellar, or other damage or loss.

Water flowing into cellars from leaks in the street taxes the ability and patience and persistence of those whose business it is to locate the source. In the old days a leak came up through the roadway and figuratively "hit one in the face." Now it is another matter. The conduits that honeycomb our streets make it easy for water to flow quite a distance from its source. Connections between these conduits and buildings make it possible for escaping water to find its way into buildings. Concrete or asphalt pavement keeps the leaks underground and causes the water to spread horizontally rather than vertically to the surface. The matter of finding leaks is a subject in itself.

One could go on for a long time discussing the variously related problems connected with service pipes such as materials used, types of curb box, joints, methods of laying, line of separation between owner and water service, cost of installation and repairs, proper size and capacity. They should furnish subjects for future discussion in our meetings to the benefit of all concerned.

The ideas and conclusions of Mr. McInnes on main pipes coincide with mine. I should like to say, however, that I think the matter of water hammer should be given more attention by water-works men, its cause, its effect, and its cure, if any. I believe we have much more water hammer in our systems than we think.

When a large main pipe breaks and there is no apparent cause to which the break can be assigned, it is unsatisfactory to leave the matter in an unsolved state, to have to say "we don't know." When every external condition is checked up, when the iron is analyzed and photographed and tested for tensile and transverse strength, there does not appear to be much left but to conclude that a sudden surge or increase of the pressure to a point greater than the resistance of the pipe caused the failure.

The fact that a large main pipe has carried on for 70 to 83 years is good evidence that the essential qualities of a good pipe were present, and the detrimental factors were either missing or present only in small measure.

Whether there is a breaking down of the structure in a cast-iron pipe as its age increases similar to what is called "old age" in living matter, is an interesting question.

THAWING FROZEN WATER PIPES.

BY GEORGE H. FINNERAN.*

[*Read January 14, 1931.*]

While thus far the winter of 1930–1931 has been unusually mild, there is no certainty that it will continue to be so. Weather forecasting has not reached the point where temperature may be foretold beyond a few days. As many of us have sad recollections of trying times during the winters of 1904, 1912 and 1918, especially the last, and as there is no assurance that the experiences of those winters will not be repeated, it seems to me to be well, to recall to our minds the lessons learned during those eventful days and the conclusions reached as to the best means and methods for meeting a possibly similar period in the future. Preparedness is half the battle won. Furthermore, there may be many who are now managing the distribution of water but who were not on the firing line twelve years ago and have never faced a situation such as we had in New England at that time.

In the early days, a frozen pipe was usually thawed by the introduction of hot water. This was done by means of a block-tin tube, which when a $\frac{5}{8}$- or $\frac{3}{4}$-in. pipe was to be thawed, was of $\frac{3}{16}$-in. bore. As fast as the ice melted, the tube was pushed forward until it finally ran into liquid water. It did not always reach the water, however, as it was often stopped by obstructions in the form of curb cocks, or sharp bends in the pipe. Sometimes, if the service pipe was of lead, a flattened or jammed part was encountered, and that was the "end of the route." Again, if the operation continued for some time, the block-tin tube became hot and soft and could not be pushed forward to follow up the ice. When an obstruction of any kind was reached, there was nothing else to do but dig, and that was neither easy nor quick with deep frost in the ground.

Next came the use of steam. This, also, was carried into the frozen pipe through a tube. Steam was more successful than hot water because, under sufficient pressure, it converted the melted ice into hot water, which in turn dissolved more ice. Today, the use of steam is a successful and satisfactory method for thawing a straight run of pipe that is frozen for a short distance out from the cellar wall. Curb cocks and sharp bends interfere, as in the use of hot water, however, because it is necessary to follow up the ice with the tube.

Where iron pipes 4 in. or more in diameter are frozen, the use of steam in sufficient quantity and under adequate pressure is the only sure method. A large boiler is necessary in such cases, and entrance to the pipe should be made at intervals, to be determined by existing conditions.

While experiments in thawing frozen service pipes by electricity were

*Superintendent of Water Service, Boston, Mass.

successfully made in a few places previous to 1904, it was not until that year that we tried electricity in Boston. The winter of that year was unusually cold; as a consequence, we had many frozen pipes. Of the pipes frozen, we thawed 62 by electricity. Some data compiled at that time give the following information:

Number of pipes thawed: 62.
Sizes, length and material of pipes: 135 ft. of 3-in. iron pipe; 60 ft. of 2-in. iron pipe; 300 ft. of 1-in. iron pipe; 3 157 ft. of $\frac{5}{8}$-in. lead pipe.
Total electrical ground distance: 16 313 ft.
Average electrical ground distance per service: 263 ft.
Average characteristics of current: 200 amperes; 35 volts.
Average time required per service: 12 min.

There were several especially long jobs, the time required for thawing being as follows:

One 3-in. iron pipe, 45 ft. long, required 1 hr., 15 min.
One 3-in. iron pipe, 90 ft. long, required 2 hr., 30 min.
One 2-in. iron pipe, 60 ft. long, required 47 min.
One $\frac{5}{8}$-in. lead pipe, 28 ft. long, required 1 hr.
Two* $\frac{5}{8}$-in. lead pipe, 130 ft. long, required 48 min.
A $\frac{5}{8}$-in. lead pipe had the current running through it for $2\frac{1}{2}$ hr., when it was discovered that the curb cock was closed.
A $\frac{5}{8}$-in. lead pipe was heated for $1\frac{1}{2}$ hr., when the curb cock was found to be closed.
Another pipe was dosed for $4\frac{1}{2}$ hr., when the current was shut off and upon digging, a stoppage was found in the pipe.

When thawed by electricity, iron pipes frequently develop stoppages as the onflow of water disengages the rust from the pipe walls and packs it solidly between the pipe and the ice core. Many mistakes were made and much unnecessary effort expended in our first season of thawing by electricity, but much was learned to be usefully applied later. The thawing outfit used in 1904 included a double team carrying a transformer to be used with alternating current; a water rheostat, consisting of a barrel containing a brine solution, two electrodes, one stationary in the bottom of the barrel, the other adjustable, to be lowered or raised; switches, ammeter and voltmeter. By means of the transformer and water rheostat, the primary alternating current taken from overhead street wires, was reduced to a voltage of about 50, and an amperage varying between 250 and 300.

An Edison lineman was employed to make connection between the overhead wires and the primary circuit. This man, together with a skilled electrical operator, two helpers, a teamster and a water inspector, constituted the force. One of the secondary wires of the outfit was connected to the service pipe to be thawed, inside the house, and the other to a hydrant in the street. Where direct current was used, a connection was made with one of the outside Edison three-wire, 220-volt circuits. The current was

*These were thawed simultaneously.

passed through a water rheostat for reduction and carried by a wire directly to the service pipe inside the house, whence it flowed through the service to the main and was grounded.

The thawing of a frozen service pipe by electricity is brought about by the heat in the lead or iron, created by its resistance to the passage of current. This heat is taken up by the ice; the ice nearest the wall of the pipe melts and allows the water, under pressure from the main, to flow through the space thus made. The continued flow of water wears away more and more of the ice core until it disappears. If the water is not allowed to continue to run after it starts to do so, the ice will again make contact with the walls of the pipe, and the water will stop flowing. The big factor in this refreezing is the low temperature of the ground around the pipe.

In thawing a frozen pipe by means of hot water or steam, the ice has to be entirely melted before water will flow.

Another cold winter was experienced in 1912, and was accompanied by frozen pipes. Again the electrical method of thawing was used to good effect. During that winter, we thawed 105 pipes electrically. Of course, many frozen pipes had to be thawed by hot water or steam, because electric wires were not conveniently near. The average cost of electrical thawing was found to be $14.14.

Until 1918, there was, so far as Boston was concerned, a welcome respite from frozen pipes in any number. During the last few days of December, 1917, however, there descended on us, a wave so cold and so persistent, that it is said that a certain torrid resort, which we sometimes urge our unfriendly friends to visit, froze. According to the Weather Bureau at Boston, the average mean temperature for December, 1917 and January and February, 1918, was 24° F., whereas the average mean temperature for the same three months during the previous 48 years was 28.9° F. It is needless to say that this long cold spell produced a considerable amount of congealed water, located in various pipes, hydrants and meters.

Our records in Boston show that 2 633 service pipes, 6 720 linear ft. of main pipe, principally dead ends and pipes on bridges, 479 hydrants and 6 812 meters were frozen. As the situation developed, one means of thawing after another was used, until at the time of maximum effort the following equipment was in service:

2 storage batteries operated by the department.
3 storage batteries operated by the Edison Company.
8 overhead electrical outfits furnished by a contractor.
10 small steam boilers.
2 large steam boilers.

Those of us who passed through the ordeal of 1918 know that the courage, resourcefulness, fidelity, patience and persistence, characteristic of water-works men, finally won out.

In the emergency, electricity was an invaluable means of relief, but we learned that it must be employed intelligently, if damage to the pipe

system is to be avoided. I have particular reference to the use of storage batteries. While we used them to very good effect, we learned that a skilled and, if possible, experienced man, should operate them. There is much danger of subjecting the pipes to too much current; indeed this danger is present in all electrical thawing. The consequences are damaged couplings, dried-up washers in couplings, and melted lead pipe, all of which result in leaks.

In using storage batteries, they are connected in series into groups of eight 2-volt cells. We had three of these groups on a truck from which, by rearrangement of wires, we could draw 16, 32 or 48 volts as required. We seldom needed over 16 volts, and frequently only 8 to 12 volts were necessary. It is well to arrange some of the batteries in groups of 4 cells in series, so that if only 8 volts are needed they are quickly available. Of course, any combination may be made by a skilled operator. The proper arrangement calls for a minimum use of current at all times.

There are many disadvantages in the use of storage batteries. The initial investment is fairly large; when not in use the batteries have to be charged and looked after carefully; they are heavy to handle; the acid spills on things generally, and on the clothing of the men in particular; they require eight hours to be recharged; they deteriorate quickly, due to heavy discharging, etc. Except in an extraordinary situation, I would not advise their use for thawing.

At the March meeting in 1918, David A. Heffernan of Milton, one of our ex-presidents, and an active and interested member of this Association, read a paper on conditions in his town during the trying period, and how he successfully met them. Out of the discussion that followed, there developed the appointment of a committee to gather all the information available relative to thawing frozen pipes. The committee consisted of F. A. McInnes, Frank J. Gifford, David A. Heffernan and Thomas E. Lally. At the convention in September, 1918, this committee made its report which was comprehensive, concise and valuable. The conclusions and recommendations pointed to the use of a motor-generator set for "all round, efficient and economical work." I think that whatever thought, study, research or experimentation water-works men may have given this matter will confirm the conclusions and recommendations of that committee.

For the past 10 years Boston has had a motor-generator set. It was assembled in our own shops and is mounted on a trailer that can be pulled by any truck available to wherever it is needed. The outfit comprises a low-voltage dynamo (50 volts), close-coupled to a 40-h.p., 4-cylinder, truck-type, gasoline motor, a switchboard, rheostat, ammeter and voltmeter, and other equipment. This outfit has served us successfully so far, and while it would not be sufficient to cope with another cold wave like that of 1918, we can get within a short time from several concerns additional equipment of this sort. There is always the electric lighting and power company to fall back on for the necessary number of outfits similar to those employed

in 1918. With the increased use of electricity since 1918 and the accompanying extension of wires and conduits, there will be very few localities where current is not available for use in thawing frozen pipes.

While I have referred almost entirely to frozen service pipes, there remains the important matter of thawing frozen hydrants. The present method used in this work, like that in service-pipe thawing, shows some advance, over that of the past. Hot water was the agent used until recently. Steam was also employed, and is today. In some cases in the past, fires were burned around the hydrant when it was frozen above ground. Today, however, unless the ice has penetrated into the pot and out towards the main, the most efficient equipment I know is the Ross thawing device. It includes a tank of acetylene gas, a water tank and a heating coil, all mounted on a base board, and easily transported. The gas is under pressure and when ignited throws intense heat through and around the coil, through which water is forced by means of a small hand pump. The intense heat on the comparatively large heating surface converts the water in the coil almost instantaneously into hot steam that is conducted through a hose into the hydrant barrel. The jet of steam that issues from the hose will bore a 2-in. hole through a cake of ice the size of any average hydrant barrel, in about a minute. This type of thawer is carried on every pumper in the Boston fire department. When a hydrant is found with caps frozen, or ice in the barrel, the firemen proceed at once to use the Ross thawer. Our own men employ it during the winter when occasion requires. We have eight outfits in the department. When the ice runs out towards the main, we use a larger and slower steamer.

From time to time, I hear the question asked whether cast-iron pipes laid with non-metallic jointing compounds will carry electricity. A few years ago I made tests to learn something about this matter and found that where the non-metallic joint was new, it acted as an insulator; no current would pass through it. We could make a line of pipe, in which joints of this kind had been used, a conductor, by inserting lead wedges in the joint space before pouring the joint. The lead, of course, would remain in the joint and permit the passage of the current from pipe to pipe. I have found that underground pipes with non-metallic joints will allow current to travel on them if the soil is moist. The current by-passes the joint through the soil. I have passed current through a line of pipe which had been in the ground for 15 years; the joints were non-metallic. Upon exposing one of the joints it was observed that a film of rusty-looking material covered the face of the joint. This film resembled iron oxide and apparently afforded the current a path by which it flowed from pipe to pipe. Whether this condition will develop in all non-metallic joints as time goes on, is a question. If it does, the joint will cease to be an insulator.

For the benefit of those who may wish to go further into the matter of means for and methods of thawing frozen pipes a few references follow on page 53.

Discussion.

David A. Heffernan.* Those members who were superintendents in the severe winter of 1917–1918, to which reference has been made by President Finneran, will not soon forget it. In Milton about 140 services froze, and 3 short lines of dead end mains. During the earlier part of the freezing season our thawing operations consisted of running a block tin tubing, through which boiling hot water was pumped, into the service. This method was satisfactory at first when the services began to freeze from the cellar wall outward, but was not efficient when the frost had worked into the ground to the depth of the pipe. It became necessary to hire an electric thawing apparatus and a man from the Edison Company, who connected the machine to the main power lines for the different jobs. The apparatus proved entirely satisfactory and thawed the services quickly and economically. Since that year we have had no occasion to make further use of this type of apparatus, and have not felt it advisable to invest in one.

We are very strict about the operation of hydrants. No one not an employee of the fire or water department is permitted to operate them. If a contractor needs water for building or other purposes, one of our men opens the hydrant and sets a meter on it, closing it in the afternoon. Two of our employees are call-men in the fire department, and they make sure that hydrants used at fires are tightly closed. The drainage system in Milton is not complete and will not be for many years. We, therefore, have the problem of preventing damage due to ground water in the hydrant barrel. This winter a number of them were filled to the grade line. In order to prevent freezing we place denatured alcohol in the hydrants and we find that it works out very satisfactorily as we have never had a frozen hydrant at a fire.

Henry T. Gidley.† At Fairhaven quite a number of pipes froze during 1917–1918. We thawed them mostly with an apparatus similar to that described by Mr. Finneran. This was furnished by the electric light company. We averaged up the cost of the thawing, and charged the consumer half the cost, or about four dollars. All paid cheerfully except two.

S. A. Agnew.‡ We have had some freezing troubles at Hingham. We never had the elaborate steam outfit for thawing that they have in Boston. Generally, some of these little towns manufacture their own outfit. In our case, we have found that we can do far better work with hot water than with steam, because of the fact that our steam apparatus wasn't large enough to produce steam at high pressure at the end of the tube. We found that the steam condensed. The result was that we changed from steam to hot water, using the same apparatus.

Roger W. Esty.§ It might be interesting to those who haven't a

*Superintendent of Water Works, Milton, Mass.
†Superintendent, Fairhaven Water Company, Fairhaven, Mass.
‡Superintendent of Water Works, Hingham, Mass.
§Superintendent of Water Works, Danvers, Mass.

Ross thawing machine to know the speed with which it can get up steam for thawing. Four or five years ago we took a piece of 2-in. pipe 5 ft. long, filled it with water, set it outdoors for the night and let it freeze. The next morning, we got the apparatus out and in 14 seconds got steam up; in 35 seconds more we had a hole through the 2-in. pipe. We do not keep the machine at the water-works shop. The ladder truck answers all alarms, and the machine is on the ladder truck. One of our men answers all fire alarms with the truck, and he is there to operate the thawer if necessary. The firemen have also been instructed in its operation. They can handle it if our man doesn't get there soon enough. If we have a frozen hydrant we use the machine, refill the tank and put the machine back on the ladder truck. The tank holds two gallons, one gallon of water and one gallon of alcohol.

JOHN F. SULLIVAN.* We have one of the Watertown machines and have never lost a service, while formerly we had a lot of trouble with leakage at joints. Last year I used the machine on six or seven freeze-ups with very good results. I have recommended it, but I don't think it is on the market any more. We also have one of the Ross machines and have success with it. We have two men testing hydrants all winter. If the hydrants freeze, we thaw them out. If we get a fire at night, each section of the city has a man in the water department who goes to the fire, and we don't get frozen hydrants very often.

I have not tried the machine on copper pipes. I hope all superintendents will be cautious and keep copper pipes low enough in the ground so they will not freeze.

REEVES J. NEWSOM.† One thing that was observed in Lynn in the year 1918, when thawing was much needed, was that direct-current thawing, whether from storage batteries or from a direct-current circuit, was not so rapid as that done with alternating current. The explanation seemed to be that there was a physical advantage in the use of alternating current in that the continuous reversal of the current set up a physical vibration in the pipe which hastened the action, whereas when direct current was used results were entirely dependent upon heat.

Along the lines of charging for doing this work, I remember that we attempted it at that time and got into certain difficulties. We felt that it was rather unfair to charge a man for the thawing of his service line out in the street, but there were many cases where the services were thawed and the pipe would re-freeze within the first 24 or 48 hours. This would occur unless the people in the house kept the water running. So, we determined upon a policy of charging for the second thawing. The number of re-freezes was gaining on us all the time, and we were unable to keep up with the job. Hence, we sought by that means to cut it down. As soon as this policy was put into effect, the people began to be more careful about letting the water

*Superintendent of Water Works, Chicopee, Mass.
†Vice-President, Community Water Service Company, New York, N. Y.

run. The first thing we knew we had all the pumping apparatus in the station running and we were still losing head in our reservoirs. As I recall it the city was using normally about 7½ m.g.d. before cold weather started, but as a result of charging for thawing the second time, we were for many days pumping at a rate of 17½ m.g.d. and still losing water from storage.

JOSEPH A. HOY.* In 1918 in Worcester we had 6 000 calls for frozen services and 3 600 calls for frozen meters. We found that the men accomplished more with a block tin tube than electric equipment installed by the Worcester Electric Light Company. Five to seven men were required for electrical thawing. The average cost on practically every service was approximately $11. As Mr. Finneran says you can get along all right with hot water, but when you strike curvatures and angles you are practically done. With electrical apparatus it is different.

MR. FINNERAN. As to charging for thawing services. In Boston we used to decide as to whether or not a charge should be rendered according to the location of the ice in the pipe. That usually was not hard to determine when we used thawing tubes.

If, when the tube was inserted in the pipe, in the cellar of the house, it encountered ice within the limits of the house or property, and it continued pushing through ice for a certain distance and finally worked its way into clear water, we assumed that the freezing started on the owner's premises, and we rendered a charge accordingly.

If the accompanying conditions were adverse, such as a cold cellar, or open or broken windows, or doors, there seemed to be no doubt about it.

If, however, when the tube entered the pipe, and it was pushed freely through clear water until it got out under the roadway or near the main, before it struck ice, we assumed that the freezing started outside the owner's property, and in such a case, we assumed the cost of thawing.

But now, with the electrical method and without the tube it is impossible to tell just where the ice is. There may be only a short section of ice out at the corporation cock and the remainder of the pipe may be clear. The electricity will heat the entire length of pipe, the thawing of the ice will take place, but we do not know whether the ice was within or near the owner's property, or out under the roadway, or at the corporation cock.

With such uncertainty or lack of knowledge, it is a difficult matter to sustain a charge against the owner, unless perchance, there is a noticeable lack of proper protection against freezing on his premises, which we may use as a basis for a charge.

Many owners, where the house sets back a considerable distance from the street, lay their pipes quite shallow. That is done, I presume, to save money in excavation. With insufficient cover the pipe will easily freeze. We find such conditions frequently to be the cause of freezing.

Sometimes the city or water company is negligent. In laying pipes in

*Foreman, Worcester Water Department, Worcester, Mass.

rock there is a tendency not to excavate deeply enough with the result of a shallow trench, in which the rock back-fill will facilitate quick freezing.

Then again in laying a pipe in a street where there are other pipes and conduits, there is a tendency to pass over these obstructions, rather than under, because of the extra depth. The consequence is a frozen pipe.

With the electrical method of thawing combined with other uncertainties as to the origin of the ice in a pipe, it is not easy to decide on a charge for thawing, and the consequence is, that the city is now assuming the cost of thawing practically all frozen service pipes.

HOWARD M. KING.* We have two large thawing machines powered by two Knox 4-cylinder engines that we had on hand. We used the forms that the engines were mounted on and put a subframe under them with steel wheels, so as to run the outfit on or off a large truck which is used for transportation.

Power from the engine is delivered through an 8-in. wide silent chain which runs a General Electric direct-current generator. This at 1 250 r.p.m. delivers 500 amperes and 60 volts. The switchboard has Western Electric dials graduated to 75 volts and 750 amperes.

There are two spools of No. 42 copper wire stranded up to $\frac{3}{8}$ in. and insulated, with a length of 250 ft. each, giving a span of 500 ft. Each wire is permanently connected to the outfit and can be reeled or unreeled without disconnecting. The machine weighs about 3 700 lb. and so far has worked satisfactorily.

JAMES W. GRAHAM.† From what I have heard, I think perhaps Massachusetts is as hard hit in the freezing of services as Maine. We had the same experience as Massachusetts in 1918. At that time the electric light company rigged up an apparatus similar to the one described by Mr. Finneran, and it worked very satisfactorily but was rather expensive. In 1925, we purchased a thawing machine from the Engesser Electric Manufacturing Company of Watertown, N. Y., which has been referred to by a previous speaker. We have used this machine off and on every winter with very good success. Last winter we sent it out into the country about 10 miles, for a local doctor who had a stock farm. He had about 500 ft. of 2-in. pipe from a well. This pipe had become frozen. Our men went out in the morning, thawed the service and were back at noon. For ordinary freezing of services we use the method of the block tin pipe and heat the water, but if we have severe freeze-ups we take out the electrical machine. This machine is equipped with a special-design 500-ampere generator. The engine is assembled from special Ford parts, equipped with electric starter, storage battery, Delco ignition and forced feed oil pump. The alternating-current voltage ranges from 5 to 100 volts. The machine is mounted on 3 wheels and its weight is 1 800 lb. It costs $1 200.

HORACE J. COOK.‡ For the past few years, the Auburn Water District

*Superintendent, Water Department, Springfield, Mass.
†General Manager, Portland Water District, Portland, Me.
‡Superintendent of Water Works, Auburn, Me.

has been using red brass pipe for services. A year ago one of these froze, and we thawed it with our electrical thawing machine. It took about 20 minutes. As far as we could see it did not affect the pipe. Our worst job along this line was the thawing of a 12-in. main. Our electric lines were attached to hydrants several hundred feet apart. Of course we could not tell how many feet of pipe were frozen but the current was on for about 12 hours.

Our usual method of thawing services is by the use of hot water.

MR. FINNERAN. I have been curious to know how copper pipes will act as conductors of electricity. As I understand, heat generated in a frozen service pipe is due largely to the resistance to the current as it passes through the envelope of lead or iron as it may be. Now, copper is considered a very good conductor of electricity, and accordingly there should be very much less resistance there.

MR. COOK. The red brass pipe we thawed contains 85 per cent. copper. This would probably thaw easier than a copper tube. However, the wires which we attach to the service are of copper. These become warm and will melt the snow and ice on which they rest. If these copper wires will heat, it would seem that the copper tube would warm up and thaw the ice inside.

REFERENCES.

Thawing Frozen Water Pipes with Electric Current. D. D. Ewing and C. F. Bowman. *Bulletin 7*, Engineering Extension Service, Purdue University, August, 1924.

Electric Thawing of Water Services. J. W. Turner. Engineering and Contracting, *Water Works Number*, July, 1924, p. 58.

Thawing Services by a Self-contained Gasoline Electric Apparatus. E. G. Wilson. *Water Works Engineering*, December 17, 1930, p. 1835.

Current Practice in Thawing Frozen Services and Hydrants. F. A. McInnes and J. M. Goodell. *Jour. A.W.W.A.*, XII, 1924, p. 393.

Thawing Out Frozen Services. D. A. Heffernan. JOUR. N.E.W.W.A., XXXII, 1918, p. 133.

Report of Committee to Investigate Conditions in Water Distribution Systems Arising from Severe Cold of Winter of 1917–1918. JOUR. N.E.W.W.A., XXXII, 1918, p. 267.

EXPERIENCES WITH WATER MAINS AND CEMENT-LINED PIPE AT DANVERS, MASS.

BY ROGER W. ESTY.*

[*Read December 10, 1930.*]

In the beginning of the seventeenth century the English began to colonize what is now New England. About 1628 Salem was settled, and the original grant of land extended to three miles north of the Merrimac River, which is now the State line, to three miles south of the Charles River.

As time went on, settlements sprang up, until a colony, which is now known as Danvers and Peabody, sought to be set off as a separate parish. On June 9, 1757, a bill was passed by the General Court which made Danvers a town. In 1855 the southern part of Danvers was set off as a separate town and called South Danvers. Thirteen years later it changed its name to Peabody.

About 1870 it became evident that Danvers should have a water system, and in 1874 an act was passed by the General Court which authorized Danvers to establish a water-works system. In 1875, by another act, the Commonwealth of Massachusetts, which was seeking a source of supply for the hospital it was building in Danvers, was authorized to join with Danvers in obtaining a water supply. Late in 1876 the system was completed, and water was turned on. At that time the population of the town was about 6 000. At the present time Danvers has a population of approximately 12 000, and it also supplies the town of Middleton, which has a population of about 1 600. For the past few years these two towns have had a combined consumption of about 1.5 m.g.d. There are 3 000 active services, of which 41 per cent. are metered, accounting for 65 per cent. of the water because three of our customers use about 50 per cent. of the metered water.

The original street mains were sheet wrought-iron, riveted together longitudinally and lined with cement. The pipes were joined together with a sleeve which was filled with cement before encasing the entire pipe in cement. We still have in service today about 60 000 ft. of this kind of pipe.

For 54 years the works have used wrought-iron cement-lined pipe for services, and today we have about 500 services that are from 50 to 54 years old and are still giving satisfactory service.

We have 185 000 ft. of plain cast-iron pipe, 55 000 ft. of centrifugal cement-lined cast-iron pipe, 65 000 ft. of the old sheet wrought-iron pipe, 44 000 ft. of cement-lined wrought-iron pipe, classified as street main, and 195 000 ft. of cement-lined wrought-iron service pipe. Thus, we have

*Superintendent, Danvers Water Works, Danvers, Mass.

65.33 miles of street mains and 36.97 miles of service pipes, or a total mileage of 102.30. There are 857 gates and 388 hydrants.

For many years we have been replacing the old street mains and service pipes. While some of this work has been done from money derived from bond issues, we try to do the greater part of it from our earnings, which are about $100 000 a year.

Since we felt it advisable to do all our own construction work we purchased last year a trenching machine and compressor. With our seven regular men and 15 to 20 extra men, and with our new equipment, together with other valuable equipment that we already had, we felt that we were pretty well organized for a small town, to do our own construction work.

Our equipment consists of a Parsons No. 21 trenching machine, a Metalweld air compressor mounted on a Reo chassis together with a 500-g.p.m. centrifugal pump, and a back-filling attachment, a Reo truck with a portable derrick, a Brockway truck, a Dodge truck, a Ford truck, and a Studebaker coupe. We have furthermore a 3- and 4-in. gasoline-driven diaphragm pump, a gasoline-driven hoisting machine, and numerous other pieces of smaller equipment.

I shall recount some of our experiences with various types of pipes and some of our construction methods.

Choice of Material. In purchasing pipe care should be exercised in the kind selected, so that pipe will be chosen that is suitable for the existing conditions and for the demands placed upon it. There are numerous kinds of pipe on the market, but the best known are cast iron, steel, wood and concrete. Each has its place in the water-works field, but for distribution systems cast-iron pipe seems to be best. Steel, wood and concrete pipes are generally used for large conduits, conveying water from some remote source to the distribution system or to reservoirs within the city limits. For general purposes cast-iron pipe predominates.

The proper class or weight of pipe is a very important matter in purchasing pipe. There are numerous classes to choose from, and a class that will meet the specifications will surely be found.

At present, there are two types of cast-iron pipe to choose from; the so-called sand-cast pipe and the centrifugally-cast pipe. While there has been some doubt in the minds of some of the water-works superintendents and engineers about changing from sand-cast pipe to centrifugally-cast pipe, it has been my experience that there should not be any fear whatsoever about the new type of pipe. I feel safe in predicting that within five years the factories will abandon the manufacturing of sand-cast pipe and will manufacture only centrifugally-cast pipe. We have laid approximately 60 000 ft. of 4- to 20-in. centrifugal pipe, and we have been satisfied in every respect.

Inspecting and Handling Pipe. Many have asked, "Is it worth while to have pipe inspected at the foundry?" I say, most emphatically, "It is very essential, and the cost is very reasonable; it is cheap insurance." How

much, for instance, does it cost to inspect 6-in. centrifugal pipe? It costs $.00325 per ft. for 6-in. unlined pipe, and $.00420 for cement-lined pipe. Inspection of 8-in. unlined and cement-lined pipe costs $.004625, and $.0060 per ft. respectively.

It has been our experience in examining the inspection reports, that out of every 100 lengths of pipe inspected, an average of 7 to 8 are rejected. Having pipe inspected at the foundry does not, however, make the inspection complete. It must be inspected for damage during transit when it is unloaded from the cars; also after it has been distributed along the trench, before it is put into the ground. These inspections are necessary if a cracked length is not to show up when pressure is applied. In 60 000 ft. of pipe, we have had only one length that was cracked and had to be removed from the line.

Care should be exercised in unloading, particularly if a contractor is doing the work, not to drop the pipe, or bang it over other pipe, or against the car or truck. We must remember that cast-iron pipe is more or less rigid and brittle and cannot be handled like wrought-iron or steel pipe.

Laying Pipe. I have found it helpful, in distributing pipe, to mark off on the highway sections 48 ft. long so that the men unloading will place either four lengths of 12-ft. pipe, or three lengths of 16-ft. pipe into each section. If this is not done, it means that there will generally be a shortage of pipe. Always have the men head the bells the way it is proposed to lay the pipe. It costs money and time to turn pipe around.

All other material, such as gates, hydrants, boxes, branches and bends should be distributed in advance of the work. Gates in service should be located and well marked; service and gas pipes should be staked out, particularly if a trenching machine is used. All this should be done well in advance of trenching and laying.

We use our trenching machine as much as possible on the work, such as for digging the main trench line, services and hydrant branches. This machine cost us $6 000. It will dig a trench 7 ft. deep and 22 in. wide and has various digging speeds up to 6 ft. per minute.

We generally dig a trench 5 ft. 2 in. deep and 19 in. wide. The machine has 18-in. buckets, but with side-cutting teeth we can obtain the additional width. Our best day's work has been 980 ft. in 6½ hours. This was through all kinds of soil. However, it is not practical to dig a length of trench much in excess of the length of pipe that can be laid in one day.

In laying pipe, we roll the small sizes (4- and 6-in.) into the trench by means of ropes. On 8-, 10-, and 12-in. work, we use our portable derrick on the Reo truck. This derrick is very convenient and economical and speeds up the pipe laying considerably. It is very handy in setting hydrants or removing them from a hole.

We have one operation in the laying of pipe which appeals to me as being one of the most important factors in laying pipe right. This is the placing of blocks under the pipe. While to some it may seem expensive and

unnecessary, it has its advantages in that it places the pipe on a firm bearing. It raises the pipe sufficiently to allow yarning and the running of the joint without digging much of a bell hole. In back filling, it allows the material to be washed under the pipe without settlement of the pipe, affording an even fill of fine substantial material. It prevents the pipe from settling onto a rock or broken-out ledge. No pipe should be laid where ledge has been removed without using these blocks under the pipe and at its sides. The common procedure of placing dirt under the pipe, back of the bell, is, in my estimation, bad practice.

What happens to pipe when the water reaches the dirt and softens it to a mush? The only thing it can do is settle. It may settle onto a rock about midway along the pipe, and then,— some cold and stormy night when you are either comfortably settled by the fireside listening to the radio, and enjoying that good cigar, or are snuggled away in your warm bed,— bang goes the telephone, and on the other end an excited voice informs you of a break in a line you recently laid. After getting the emergency crew out into the cold night to close off the district and dig out the break, what are you likely to find? You will generally find that the pipe settled onto a rock, and the earth load caused it to break at that point of contact with the rock.

I had a similar experience years ago. While laying a new suction main into the lake we paralleled it with a 4-in. cast-iron pipe from the relief side of the pumps. This pipe was laid across some sheeting that had been cut off, and the pipe was covered with about 6 ft. of fill. When we opened up the line on placing the steam pumps in operation, the water boiled up in the station yard instead of running into the lake. We dug up the pipe and found that it had broken off where it rested on the sheeting. The pipe had settled so that the top of the pipe on the pond side of the break was about an inch below the bottom of the other pipe, indicating a settlement of nearly six inches. This experience taught us to lay all pipe on blocking and on firm ground.

Consequently, in about 60 000 ft. of pipe laid during the past five years, only one length of pipe has had to be removed subsequent to testing.

How expensive is this blocking? A block is generally about 9 x 8 x 2 in. in size. At the rate of $35 per 1 000 board feet such a block costs $.035, or approximately $.003 per running foot of pipe. Sometimes we purchase the blocks from some one lumbering locally. We do a lot of watershed reforestation and are generally able to get enough logs to cut into blocks to carry us through an average year.

Pipe Joints. I think that it is generally accepted in all progressive water-works plants that a lead substitute is more satisfactory and economical than lead. There are numerous substitutes that have proved satisfactory. We have been employing a substitute since 1919 and have had many interesting experiences with it. This substitute has saved us a great deal of money and hard labor. It is easy to prepare, and once brought to

the right consistency and poured into the joint, you need not fear that you have not provided a lasting and dependable joint. It is the most dependable material that can be used under railroads, over bridges, or similar structures.

We have had numerous joints that were poured with lead and pushed out. I recall a line passing over a causeway that leaked at the same joint three times. The last time the lead pushed out entirely at the top of the joint. We melted that joint out together with three others and poured them with the substitute material; since then we have had no trouble.

It has been my experience that a compound joint will not push out. In preparing the material make sure that it is brought to the proper temperature, *i.e.*, have the surface appear as clear as a mirror, do not have it boiling or too cool. When it runs as freely as water, it is ready for pouring, and a perfect joint will be produced.

Assuming that you do not have enough material when you first pour the joint, and you have the joint only about ¾ full, get some more and pour it in. It will weld or blend in such a manner that it will not affect the strength or tightness of the joint.

We use braided jute entirely in laying pipe and use only one strand to a joint. While braided jute is about double the price of loose jute, there are many advantages in using it that makes the cost a minor factor. There is no waste. It can be cut to desired length and placed along the bank. It affords a means of lifting the spigot end for insertion into the bell. This operation automatically yarns the lower part of the joint. It produces an even joint all around the pipe, always centering the pipe. It produces a joint of even depth, and the joint will not be full of jute. Jute does not make a joint tight. Use it sparingly. As a rule, the bell is 4 in. in depth. In using braided jute a joint of at least 3-in. depth will result.

It has been my experience on contract work to always furnish the material, whether it is pipe, fittings or the jointing material.

Pipe Cutting. Extreme care should be taken in cutting pipe. Most water-works men cut it with a hammer and dog chisel, one man striking, another holding the chisel, and a third rolling the pipe. If this method of cutting is practiced, make sure that the cutting chisel is sharp, for if it is not you may crack the pipe. We cut all our pipe with an Ellis wheel cutter. This is a one-man job as compared to the three-man job previously mentioned. We hold the pipe with chain tongs, one on each side, and with only a few turns back and forth with the cutter the pipe will be cut even and clean.

Gates and Hydrants. Do not hesitate to place an adequate number of gates in the new line. A gate should be inserted in each line entering an intersection; sometimes this means four gates at intersections. We often set one of these gates a considerable distance back from the corner, so that when the hydrant is set, it will be within the four-gated intersection.

Place gates on all hydrant connections and set all hydrants that are near intersections on the corner least exposed to traffic.

In setting hydrants, a proper base should be provided. A concrete block makes a good level and durable base. After the hydrant is set, care should be taken in wedging it properly on all sides. It should be well blocked in front of the bell of the hydrant to keep the pipe from settling and the hydrant from leaning forward. Plenty of rocks should be placed around the hydrant to provide quick drainage of the water from the barrel.

If possible, do not set hydrants in front of a building. Set them away from it, even as much as 300 ft. This allows a fire engine to work without being driven out by the heat and flames of the fire.

Another suggestion relating to pipe lines, whether large or small, is to provide air vents and blow-offs at the high and low places. These are exceedingly valuable and convenient in case of trouble to release air and to drain or flush out the pipe. Place a blow-off at the end of a line, and make sure that the last pipe is well braced to resist pressure and water hammer.

Corporation taps can be made on renewal work on the bank before the pipe is lowered into the trench. Measurements can be taken as far as 50 ft. in advance, in order that tapping may be completed without holding up the pipe-laying crew.

All branches and bends should be well anchored with a backing of substantial size, rocks or concrete.

Back Filling. Back filling, one of the most important parts of construction, is perhaps most neglected and improperly done. To me, dry tamping, particularly filling below the pipe and tamping it well, is useless and a waste of time. There is nothing so satisfactory as using water to wash the dirt under the pipe and to settle the trench. Fill the trench $\frac{1}{2}$ to $\frac{3}{4}$ full of water; then shovel or scoop the dirt into the trench. This method washes the dirt under the pipe, and the weight above compacts it better than any other method. Fill the trench to the top, forcing the water either farther down the trench, or out into the gutter.

After the back fill has had an opportunity to dry, smooth off the top. If a steam- or gasoline-driven roller is not available to roll it, use an air tamper to finish off the top. I wager that the heaviest rain storm will then not cause it to settle. All kinds of soils can be treated in this manner. Some soils are slow-drying and may require the use of lanterns and flags for two or three days to protect traffic. The fill will never settle appreciably, but do not forget, in order to be successful you must have blocking under the pipe.

Pipe Ends and Marking. What about the advantages or disadvantages of beaded or straight-end pipe? I presume that there are pros and cons for each type. However, I have never seen a hydrant blow off, and most of the pipe used between the tee and gate, and the gate and hydrant is plain-end pipe.

At the Atlantic City Convention, the question was raised as to the advisability of marking the city's name, the year, and the class on centrifugal pipe. It would be rather a difficult procedure to do this on centrifugal

pipe, as the only place available is the bell. How many times do we ever consult the name, year and class on pipe that has been laid? Probably never.

I feel personally, after watching them test pipe at the foundries, subjecting the pipe to the hammer and 500-lb. water-pressure test, that it will withstand any pressure or water hammer that it would be subjected to in either your town or my town, regardless of whether it was labelled or not.

Protective Linings. The question of protective internal coatings for cast-iron pipe seems to be a live issue today. There are various kinds of coatings, but the one that I am most familiar with is the cement lining. This is a subject much discussed in the past, but due to lining cast-iron pipe centrifugally, a great many water-works officials have been aroused and interested in this new method.

In the September 10, 1930 issue of *Water Works Engineering* I had an article on cement-lined pipe; I shall, therefore, not go into details as to its advantages and disadvantages, but should like to touch again on a few of the most important points.

One of the best features of cement-lined pipe is that there is no loss of discharge by diminished bore. That is a fact established by the examination of mains and services that have been in use for 50 years. A 4- or 6-in. main after all those years still remains 4 or 6 in. in diameter and has apparently an unlimited life.

In 1926 we laid 15 000 ft. of 20-in. cement-lined cast-iron centrifugal pipe. During the past year we had occasion to examine it where it came into our reservoir. We found the cement lining covered with a gelatinous coating. After rubbing this off, the lining had a surface similar to fine-grain sandpaper. The original glossy surface had disappeared. The same condition of surface is also in evidence in old-type cement-lined mains and service pipes. This slight deterioration is not detrimental to the carrying capacity or longevity of pipes.

It has been my experience that the present linings with a thickness of $\frac{1}{16}$ or a $\frac{1}{8}$ in. are not thick enough. Recently I purchased a carload of 4-, 6- and 8-in. pipe and specified that the lining must be $\frac{3}{16}$ to $\frac{1}{4}$ in. in thickness. The heavy cement lining in such a pipe breaks off quite evenly when the pipe is cut, whereas the lighter lining, $\frac{1}{8}$ in. or less, will flake off considerably.

I have seen linings less than $\frac{1}{16}$ in. in thickness. With the corrosive water that we have, noticing the effect of the action of the water on the lining, I am afraid that it may deteriorate to such an extent that it will prove valueless as a protective coating as years go by.

In tapping a pipe for service corporations, the drill and tap will bore a hole through the cement and will not push or flake off the lining.

The lining in the fittings, however, has been a failure in every respect. It is of course impossible to apply a lining to a fitting centrifugally, therefore some other method has to be resorted to. If the same dense lining

could be obtained in a fitting that is secured in a pipe, we would have a perfect job of lining throughout the pipe line. A wash coating is valueless. A lining applied with a brush or trowel does not have the even thickness nor density of the lighter lining applied centrifugally. It must be heavier to make up for the density and evenness found in pipe lined centrifugally.

From a line laid in 1926, we removed a 12 x 4-in. reducer which was completely covered with tubercles. Deterioration of the lining had advanced so far that the lining had nearly disappeared. We have found rust spots in lined fittings that had been lying in the yard; fittings that were only a week in stock. In some fittings lying out in the yard the lining had flaked off entirely in four years. This is conclusive evidence that the present type of brushed-on linings is valueless and that some other means to obtain a smooth and heavier lining must be developed.

I was recently at a foundry with a group of water-works men, users of cement-lined pipe and fittings. At that meeting, we examined numerous fittings from cities that had been using cement-lined fittings. One of these fittings had a $\frac{3}{16}$-in. lining that had been in for two years. That fitting was in splendid condition and did not show any signs of deterioration. Fittings from the other cities and towns were more or less filled with tubercles, and these had a much lighter lining in them.

The water lying in dead-end lines often has a peculiar taste which can be attributed to the cement lining. It is a soapy, limy taste. We have practically eliminated such tastes by placing a faucet on the blow-off and allowing a small stream of water to run continuously. This slight movement of water eliminates complaints and has proved satisfactory on a 6-in. line 1 700 ft. long. We have had no complaints from the house near the end of the line.

Use of cement-lined pipe increases the hardness of the water considerably at first, but this condition gradually rights itself. It is not injurious or detrimental to health, and the slight inconvenience at first is a minor factor considering the ultimate benefit derived from cement-lined pipe.

Discussion.

David A. Heffernan.* Mr. Esty should be congratulated on his very interesting and thorough paper. I am sure that we all got a great deal out of it. Milton is operating similarly to Danvers. We began to use centrifugally-cast cement-lined pipe for water mains in 1925 and have at present in service about 13 miles of this type of pipe ranging in size from 6 to 16 in. We have experienced two breaks, one in 10-in. pipe, and another in 6-in. pipe; both leaks occurring about a year after the pipe was installed. To my mind care in handling this pipe is very important, and I feel quite sure that if proper precautions are used in handling, cutting and blocking the pipe in the trench the pipe will give good service.

We have had a few complaints where cement-lined pipe has been used on a dead end. Some consumers protested that their kitchen utensils showed discoloration, and other complaints were about the taste. Flushing will help to halt repetition of these complaints. A few days ago, however, I did receive a complaint that the water carried through pipe lined with cement did not permit a certain gardener to grow roses in his greenhouse, although he did not know of any other plants which were affected similarly. His idea was that the water should be analyzed, and after I looked into the matter I discovered that previous to the installation of the present pipe, water had been supplied through unlined cast-iron pipe; during which time a previous gardener had also been unable to grow roses; therefore, it would seem that the present complaint against cement-lined pipe was unfounded. This meeting here today brings back memories of about fifteen years ago when in this same room very interesting meetings were conducted at which the superintendents were more active and verbose than they have been recently. It is my idea that some of the younger men, who are in charge of water works, should get up on the floor and tell us of their experiences. Perhaps they feel that their experience is more limited than that of some of the older members, but I feel quite certain that the new blood will have new ideas and we can all learn something from them.

I received a letter recently from a superintendent who unfortunately is not here today. He has given a great deal of time and thought to the study of cement lining for service pipes. He tells me that he has developed a formula for a lining, which according to laboratory tests is insoluble. My idea is that if this progressive superintendent can develop a lining of this sort the pipe manufacturers' laboratories should be progressive enough to develop something similar for use in larger pipes. Mr. Esty mentioned the lining of fittings. I think his department and mine were among the first to use cast-iron fittings lined with cement in main installations. I think that a great improvement can be made in this field too, and I believe that

*Superintendent of Water Works, Milton, Mass.

in general both pipe and fitting should carry a thicker lining of cement than they normally do at present.

W. GUY CLASSON.* I have brought with me a sample of cement lining from a 12-in. pipe that has been in service 55 years. It was found to be perfectly free from tubercles. The fittings were not lined with cement and were no better than a 6-in. pipe. On taking out the corporation cocks from the old main we found many of them filled to such an extent that it would be hard work to get a darning needle through them. About four years ago we bought some centrifugal cement-lined pipe. Unfortunately our experience with it was not so good as Mr. Esty's. We had trouble for one year with this pipe from tastes, and at last we had to install a 2-in. blow-off on the end and run it wide open for about a month or six weeks, and then throttle it down to one inch and run it all winter long before the lines would clear. Some peculiar incidents happened. One woman washed the windows at her house and invited me down to see what a nice job she had done. It certainly looked like ground glass. She had an awful time getting it off. One man washed a new automobile and you would think he had a light coat of whitewash on it.

However, since this pipe line has cleared up, we have had no trouble whatever. I am a great believer in cement-lined pipe, because this old pipe was in service 55 years, and is in such good condition. I hope the manufacturers will get so that they can line a pipe with cement and line it right.

To my mind the trouble we had four years ago was from excess lime. This lime came out in great quantities, and I often wonder how much cement is left in the pipe.

HENRY A. SYMONDS.† In pouring joints, it has been our practice in Millbury, where a joint wasn't filled with compound, to take it out and start all over again. Mr. Esty said that in his experience he could melt some more compound and pour it in. It would save us a lot of trouble if we could do the same at Millbury.

MR. ESTY. My first experience in this matter was obtained when I wanted to see just what would happen when a joint was not poured in one filling. We took a plank, poured some of the compound onto it and let it cool. We then kept building up the compound in successive pourings. Finally I broke down the mass but could not see any seams in it. Later, we were running a joint on a 12-in. pipe, and the joint was only about three-quarters full when the supply of compound was exhausted. We had to go back and get some more. When we returned, the joint had cooled, but we finished the joint with new material and put pressure on it. It is just as tight as any other joint in the line.

WILLIAM NAYLOR.‡ I have had a similar experience in using a lead substitute. I was putting on a split sleeve to tap a 6-in. hole in a 12-in. pipe.

---

*Superintendent of Water Works, Leominster, Mass.
†Consulting Engineer, Boston, Mass.
‡Superintendent of Water Works, Maynard, Mass.

When we poured the joint we didn't have enough material. We mixed up some more, and of course a few minutes elapsed before we poured it. When we tapped the pipe, I was afraid that we would have trouble, but, that joint was about the tightest joint I ever had.

MR. ESTY. I do not use compounds in tapping sleeves. I still use lead. Everywhere else I use compound.

MR. HEFFERNAN. I think it is the practice among water-works men not to use compounds on split sleeves.

HENRY T. GIDLEY.* I don't pour the whole sleeve. There is a bead on the inside of the sleeve, and I pour the sleeve just as I would an ordinary joint. In that way I get away from trouble.

MR. HEFFERNAN. What do you use, a bolt or a clamp?

MR. GIDLEY. A bolt.

STEPHEN H. TAYLOR.† I think you ought to have the benefit of our experience at New Bedford where we have poured joints on tapping sleeves and poured the whole sleeve full. We have had two cases where the sleeve has broken off, I think, due to expansion of the compound. If the joint is poured in the same way as a valve joint you will have no trouble.

ARTHUR C. KING.‡ One point that Mr. Esty didn't mention is the precaution required in tapping a large corporation cock into centrifugal pipe. We are now making it our practice not to use a tap larger than an inch and a half. After making the tap it is well not to use too much force in screwing the corporation cock into the main. There are one or two other points that Mr. Esty discussed that are of interest to me. In five years we have put in practically 24 miles of 8- and 12-in. centrifugal cement-lined mains and we used no blocking on straight work — only under the fittings. We use a railroad tamper and tamp under the whole length of the pipe before we use water for consolidation, filling under the whole length of the pipe and a few inches above. Then we turn on the water and shovel the earth into plenty of water. We have found no signs of dangerous settlement where we have followed this practice. In making taps on replacement work, we use a dry tapping machine as that is much smaller than a wet tapping machine, and tapping is not necessarily done before the pipe goes into the ground, but can be done afterwards in a small hole. When cutting the pipe we use a three-wheel Barnes type cutter, and a chain vise rather than chain tongs. A large No. 4 Vulcan vise is listed to carry 8-in. pipe, but can be used with a larger chain on 12-in. pipe. We mount it so that the jaws are horizontal instead of vertical and roll the pipe in instead of lifting it in. In pouring joints with compound we use a short-handled dipper holding enough compound for one 12-in. joint. This type of dipper is much more convenient than a long-handled lead ladle. We too have had some trouble with tastes in cement-lined pipe.

---

*Superintendent, Fairhaven Water Company, Fairhaven, Mass.
†Superintendent of Water Works, New Bedford, Mass.
‡Assistant Superintendent of Water Works, Taunton, Mass.

CALEB M. SAVILLE.* Mr. Heffernan has spoken of linings for pipes that will perhaps solve some difficulties. I think he referred to our friend, Superintendent Lourie, of Bristol, Conn. I have talked with Mr. Lourie about lining of pipe. There are many interesting things about it. There are many things besides the matter of mixture. Mr. Lourie and Mr. McKenzie, I think, of Southington, have developed an improved cone for lining service pipe. The cone that has been developed is rather an expensive affair, but is probably worth while. The expense comes in the steel springs that keep the cone centered. These springs are adjustable and can be replaced when necessary. Regarding the material used for lining, Mr. Lourie is using what is called "Master Mix," a product that has been developed by a western concern. Mr. Lourie tells me that he has experimented with this material and now has developed a compound that is absolutely insoluble in water. I am passing on to you only what Mr. Lourie told me. As to Hartford experience with cement-lined service pipes, we have used quite a lot of them, which we line in our own shop. Up to the present time we have been using cement-lined cast-iron pipes up to 12 or 16 in. in diameter. We have had considerable trouble at dead ends, with the hardness of the water. Our ordinary hardness runs 17 and 18 p.p.m., and I think it has run up to several hundred p.p.m. in some places at times. That has been overcome by employing bleeders. Unfortunately, one or two places where bleeders were used, were at high points to which it was necessary to pump water. Thus it was necessary not only to pay for the water wasted but for electric current to run the pump. I was much interested in listening to Mr. Esty and others as to their experiences with various kinds of pipe. I do not know that there are any more breaks in centrifugal pipe than in any other pipe. Our experience however may have been unfortunate with certain kinds of pipe so manufactured, and methods of manufacture may have been improved since pipes have been so made. Perhaps the products of some manufacturers of centrifugal pipe should be more carefully inspected than those of others, to be assured that the enthusiasm of the founder in getting his pipe ready for the market does not run away with his desire to get a first class product.

*Chief Engineer, Board of Water Commissioners, Hartford, Conn.

THE ATLANTIC CITY WATER WORKS.

BY LINCOLN VAN GILDER.*

[*Read September 25, 1930.*]

About 80 years ago that part of Absecon Island now known as Atlantic City was a wild strip of New Jersey beach, a narrow strip of sand dunes largely covered by red cedar trees, wild grapevines and kindred vegetation; the home of innumerable wild birds, a paradise for fishermen and gunners for bay birds, ducks, brant and wild geese.

About this time, a small colony was started whose principal function was the entertainment of visiting sportsmen largely from Philadelphia and nearby cities. The health-restoring power of the sea air also became apparent, and in 1854 the little fishing village was incorporated. Its diamond jubilee was celebrated a year ago together with the golden anniversary of the incandescent lamp.

In its infancy the water supply of the settlement was obtained largely from cisterns filled by rain falling on shingle roofs. In a few favored spots, good water was obtained from shallow surface wells, but in general the water in most of the shallow wells was so unpalatable as to make it unattractive if not actually unpotable.

About 1880, the permanent population having reached 5 500, R. D. Wood and Company obtained a franchise from the municipal councils for a municipal supply functioning as the Atlantic City Water Company. In 1882, this water company began pumping surface water at a small station situated in what is now Pleasantville on the mainland through a 12-in. cast-iron force main about five miles long, lying for the most part in salt marsh and passing under a navigable salt-water stream.

In 1888, the permanent population having increased to 10 000, another franchise was granted to a company of local citizens under the corporate name of Consumers Water Company to supply water from artesian wells lying within the city limits. About this time, the Atlantic City Water Company laid a 20-in. cast-iron main parallel to the original 12-in. main and purchased a mill pond at the head of tidewater on Absecon Creek known as Absalom Doughty Pond. Water from this pond was pumped through about two miles of 12-in. cast-iron main, to a small receiving basin at the main pumping station, while a gravity canal was being dug. After completion of this work, the original source of supply was abandoned; the stream is now used for drainage.

In 1893, the two franchises were consolidated, and in 1895 the city purchased the entire property by authority of an act of the legislature. Since August 1 of that year, the water supply has functioned as a municipal

*Engineer and Superintendent, Atlantic City, N. J.

utility under the title of Water Department of Atlantic City. At that time the census population had grown to 18 000.

The directing head of the newly created department was a board of three commissioners appointed by the mayor for three-year terms. It is a matter of civic pride as well as of immeasurable public benefit that the responsible heads of the department have taken their duties seriously and have always been conservatively progressive.

One of the earliest innovations was the introduction of meterage. The saving in consumption effected by this action has been of the utmost importance in the conservation of the water supply.

In 1901, with a census population of 29 000, a 30-in. steel force main was built from the pumping station to the city paralleling the 12- and 20-in. mains. The pumping-station equipment was increased to a total normal capacity of 14 m.g.d., and a series of artesian wells with air lift was installed, yielding about 3 m.g.d., the balance of the supply being obtained from Doughty Pond and the artesian wells driven in the city by the Consumers Water Company.

While the open canal connecting Doughty Pond with the pumping station was adequate as a water carrier, it was unsatisfactory for sanitary reasons and was subject to tidal overflow during violent northeast storms. These conditions were relieved in 1904 by building a 42-in. wood-stave conduit and closing the canal. In 1905, the yield of the Consumers wells had fallen so low that the whole plant was abandoned. The load has since been carried by the Absecon Pumping Station alone. In 1906, two 90-h.p. boilers were removed and replaced by two 200-h.p. boilers, giving a total rated boiler capacity of 650 h.p. In 1908, a 12-m.g.d. vertical triple-expansion crank-and-fly-wheel plunger pumping-engine was installed and a worn-out 1-m.g.d. duplex pump was scrapped, making a normal pumping capacity of 25 m.g.d. A census population of 43 000 plus an estimated midsummer visiting list of 250 000 on holidays and week-ends, showed an average consumption of 6 and a summer peak load of 15 m.g.d.

December 23, 1909 stands for the worst and the best day so far experienced in the history of the Atlantic City Water Department. At 3 A.M., the pumping station was put out of commission by a fire that burned everything combustible in a building, part brick, part wood, with a slate roof on wooden sheathing, the whole interior having been freshly varnished. Clearing away for repairs began before the fire was out. At 10 P.M., 400 h.p. of boilers were under steam and the largest pump started. At midnight, full pressure was restored, and the city did not suffer after this for lack of water due to the fire. Having no distribution reservoir other than two standpipes, pressure was down to the first floor by the time breakfast was over. By the help of a hose stream from the Ventnor Department and the generosity of the hotels and industries with private deep wells, however, the city did not suffer, and insurance policies expiring on that day were renewed without penalties.

That was the worst part of the experience; the best is a different story in that insurance was sufficient to recoup the actual loss, as the most valuable machinery was not seriously damaged. The old, patched and wholly inadequate building was completely demolished and replaced by a fireproof structure large enough to serve the city for years to come while the regular station duties were performed in a frame storm house inside the building lines. At first thought, the fire was a disaster, while in fact it was a blessing; for it enabled the Board of Commissioners to provide an adequate building with ample room for years to come without private qualms or public criticism.

In 1910, the old force mains were inadequate for peak loads and generally in poor condition, while the pumping station was slightly overloaded. To correct matters, a 48-in. wood-stave force main was built from the pumping station to the city, a distance of 25 500 ft. For the most part the pipe was laid in salt marsh. Three navigable streams were crossed by trestle and cast-iron inverted siphons. Two 300-h.p. Heine boilers and a 125-kw. electric generator were installed. Artesian wells were added from time to time as a part of the regular pumping-station duties; air lift had been abandoned and direct pumping by motor-driven centrifugal pumps substituted.

The most important accomplishment of 1910 was the purchase of 5 000 acres of forest and stream comprising the heart of the Absecon watershed of 10 000 acres. This purchase gave the city virtual control of the entire run-off, together with ownership of the principal stream beds and all available impounding areas.

In 1912, a 10-m.g.d. DeLaval turbine-driven centrifugal pump was installed. In 1914, a new 48-in. cast-iron force main was built from the pumping station to the city, and the three old mains 12, 20 and 30 in.in diameter, were abandoned, being beyond economic repair. That part of the main lying across salt marsh was laid on concrete bolsters supported on piling driven to firm bearing. A new dam was built at Lower Doughty Pond with crest of spillway at El. 12 above mean tide, the old crest being at El. 5, thus raising the storage capacity from about 30 to 200 m.g.

In 1916, an 18-m.g.d. turbo-centrifugal pump was installed and a part of the old equipment scrapped. In 1917, a coöperative agreement was made between eight of the leading beach-front hotels and the city whereby a high-pressure fire system was installed by the water department, and power to boost from domestic to fire-fighting pressure furnished by underwriters pumps of the various hotels. Fire-alarm apparatus is installed in every engine room, and all pumps must respond to every alarm within the area covered by the system embracing all property lying between Pacific Avenue and the Board Walk, and between Massachusetts Avenue and Arkansas Avenue, the highest valued property in the city. The pumps have a combined capacity of 10 000 g.p.m. at 150-lb. per sq. in. pressure. The

power houses give continuous service, and the system is so designed as to be readily extended without interruption of service.

In 1923, a 300-kw. turbo-generator, an 8-m.g.d. motor-driven centrifugal pump and travelling-grate stokers were installed. The latter were set under both 300-h.p. boilers. This change increased each boiler capacity by 50 per cent., relieved the firemen of their hardest and hottest work and was particularly adapted to the use of barley coal, the smallest break and cheapest anthracite on the market.

In 1925, an artesian well 675 ft. deep was bored and equipped with a motor-driven submerged turbine pump. This unit has been delivering about 900 g.p.m. and has been in constant service to date. Last year a 60-in. "Hitensile" gravity conduit was laid from Doughty Pond to the pumping station, a distance of 9 600 ft., for the double purpose of carrying stored water from Absecon Creek Reservoir and from a series of artesian wells now being constructed along the right of way. A 500-h.p. Heine boiler with Coxe stoker designed for 200 per cent. rating was also built last year.

Extensions of all kinds to the distribution system were constantly carried on as the growth of the city required them. With the early completion of the artesian wells, the supply will be approximately 30 m.g.d. with 200 m.g. of reserve. The present works have the following characteristics:

Rated pumping capacity: 48 m.g.d.
Average consumption for 1929: 14 m.g.d.
Maximum pumpage: 22 m.g.d., with a peak load of 30 m.g.d.
The high-pumpage months are: July, August and September.
The low-pumpage months are: December and January.
Population by United States Census for 1930: 65 748.
Local estimate of maximum visiting populace: about 350 000 on week-ends and holidays.

The next important additions will probably be a 25-m.g.d. centrifugal service pump and another 48-in. cast-iron force main.

As is too frequently the case with municipal water departments, we get neither cash nor credit for hydrant rentals or any other public use of water, and have an appropriation from the general tax of a sum considerably less than the value of free public service.

With our regular revenue, augmented by the tax appropriation, we carry the entire running expense of the department, including high-pressure fire service, plus interest and amortization of our bonded debt of $3 000 000 now outstanding.

Our meter rate is 12 cents per 1 000 gal. as fixed by the city council in 1902. So far, it has not been raised. The ratio of collected revenue to tax appropriation is practically unity.

Discussion.

Lincoln Van Gilder. William C. Hawley, our first superintendent of water works can enlighten you on the earlier history of the works. My account is legendary while he possesses first-hand knowledge.

W. C. Hawley.* The rate schedule of which Mr. Van Gilder spoke was established, I think, early in 1897. Water meters had been set and charges by meter rates under a former schedule began August 1, 1896. The first meter bills went out in February, 1907 just before a councilmanic election. Naturally there was a demand for a reduction of the meter rate, and after some study the rate which I believe had been 20c. per 1 000 gal. was reduced to 12c. and the city made up the difference by paying to the Water Department about $28 000 per year which was a very fair payment for fire protection and other municipal service at that time, but is undoubtedly inadequate now. Unfortunately no change was made in the minimum rates charged at that time, so that while the introduction of the meter system had reduced the per capita consumption of 250 or 260 g.p.d. to from 50 or 60 g.p.d., the incentive for waste prevention did not exist under the new rate and I have no doubt that the per capita consumption today is materially higher than 60 gal.

I want to take this opportunity to pay my respects to the Water Commissioners of the Atlantic City Department, especially Messrs. Louis Kuehnle and D. S. White who were members of the first Board of Water Commissioners and who are still living. When I took my position it was with the distinct understanding that it was not a political one and that I was to keep out of politics in every way except to go to the polls and perform my duty as a citizen. The Commissioners lived up to that agreement. It was a non-political commission and if it had not been interfered with, the city would have saved much money.

Atlantic City is fortunate in having an abundant supply of water of exceptional quality. The original supply was from a small creek on the mainland, the water of which was impounded. This was increased by excavating a small basin and driving a large number of 4-in. pipes down through the clay into the water-bearing sand and gravel. These pipes were made up of two lengths each of 4-in. cast-iron pipe. The water of Absecon Creek was brought to the pumping station from Doughty Pond through a canal, since replaced by pipe. Undoubtedly a large part of the water from Absecon Creek is water from the underlying sand and gravel which finds its way to the surface, as the run-off is much greater than can be accounted for by the rainfall on the drainage area. In later years artesian wells were drilled near the pumping station as the population of the city increased.

The supply of water for the Consumers Water Company was originally obtained from a well which was put down to a depth of about 1 200 ft.

*Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Pa.

without getting water. As a last resort the well was shot with nitro-glycerin and a good flow of water obtained, but it was highly charged with soda and magnesia. Later, water-bearing sand was located at a depth of 800 to 840 ft. and additional wells put down. This is the same stratum which is tapped by the artesian wells of many of the hotels.

MR. VAN GILDER. Mr. Kuehnle, of whom Mr. Hawley has spoken is my director today, and has served, with the exception of eight years, continuously as the directing head of the water department.

PRESIDENT ROBERT SPURR WESTON. Are the private supplies for the hotels deep wells on the island?

MR. VAN GILDER. Yes. The water you are drinking in this hotel comes from private wells, about 850 ft. deep. The same is true of most of the big hotels as well as the two leading utilities, the electric light company and the gas company, and one of the ice companies, the high school, and various other users. In Mr. Hawley's time I think that the water flowed to the surface.

MR. HAWLEY. When I first took charge of the plant, the water from the artesian wells at the Consumers pumping station would raise the valves and flow through the pumps into the tank when the pumps were shut down. As the hotels, etc. began to use water from their artesian wells the elevation to which the water would rise in the wells was gradually lowered until the suction lift while pumping was 15 or 16 ft. We then put in an air lift. After that some of those who had been pumping from artesian wells became good customers of the water department.

MR. VAN GILDER. The pumping level has fallen, until it is now about 90 ft. deep, and the water is pumped out either by air lift or deep-well turbines.

WATER HAMMER IN PIPE LINES.

ITS CAUSES, MANNER OF ACTION AND EFFECTS.

BY H. K. BARROWS.*

[*Read January 14, 1931.*]

Historical. The phenomenon of water hammer or hydraulic shock caused by suddenly stopping the flow of water in a pipe line has long been known, but its nature and effects were definitely ascertained only near the close of the last century by Professor N. Joukovsky at Moscow (1897–1898).

Prior to Joukovsky's work, Korteveg in 1878 determined the velocity of sound waves in an elastic pipe filled with a compressible liquid and Joukovsky showed that this was identical with the velocity of a pressure wave. In this country some studies of water hammer had been made by E. B. Weston (1884) at Providence, by Carpenter at Cornell University (1892–1893) and by Frizell (1897), but it remained for Joukovsky to conduct the first large-scale experiments and to frame correct formulæ for the determination of excess pressure due to sudden closure of gates.

Joukovsky's experiments and results are fully given by Miss Olga Simin,† in a paper, which was a translation, greatly amplified, of the original work.

Joukovsky's Experiments and Studies. The experiments were made under the direction of Chief Engineer Nicholas P. Simin of the Moscow water works, and his report includes a full analytical solution of the problem.

As shown in Figure 1, pipe lines, all of cast iron, including 6-, 4- and 2-in. pipes 1 066, 1 050 and 2 494 ft. long respectively, were laid on the surface of the ground in the yard of the pumping plant, each line forming a loop starting at the 24-in. main and ending at a well, where a quick-closing gate was placed. This gate was governed by a weight which was dropped to stop the flow.

Instruments as shown in Figure 1, included, (1) Bourdon manometers, located by black dots; (2) Crosby indicators at I, II and III; (3) a Marey chronograph at the pump house, connected with the points shown by square dots. All these devices were electrically timed to $\frac{1}{2}$ sec. by a pendulum at the pump house. The chronograph marked every .01 sec.

Form of Pressure Diagrams. These are schematically shown in Figure 2, where *A* is the diagram at the gate, *B* that toward the reservoir and *C* that still farther toward the reservoir. Note that the time from the point of pressure rise to the point of pressure drop remains the same in all cases; this being the time required for the pressure wave to travel from the gate (or from any other given point) to the reservoir and back.

At all points *except* at the gate, periods of normal pressure intervene

*Consulting Engineer, Boston, Mass., and Professor of Hydraulic Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

†See *Journal* A.W.W.A., 1904, pp. 341–428.

between the supernormal and subnormal periods. Also for a given point, the period of supernormal pressure equals the period of subnormal pressure and is proportional to the distance between the point and the reservoir.

Theory. Theoretically, if the velocity of flowing water were instantaneously checked and the pipe and water were inelastic, an infinite rise in pressure would result. This will never be realized, however, because it is impossible to close a gate instantly; the pipe walls can expand and water itself is compressible.

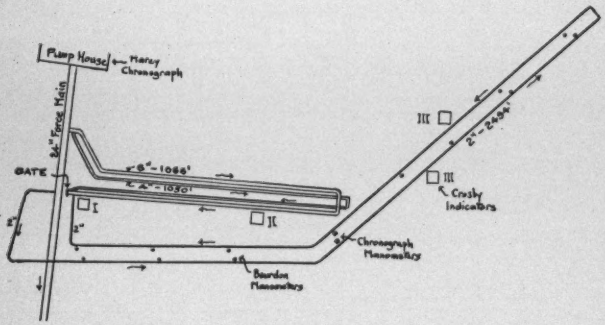


FIG. 1.— JOUKOVSKY'S EXPERIMENTS — PLAN.

Four periods, or cycles, may be identified in analyzing the effect of gate closure. These are best discussed by considering very short equal sections of pipe near the gate, called 1, 2, 3, etc. (See Figure 3.)

(1). When the gate is closed, section 1 is brought to rest and its kinetic energy transformed to pressure energy; the water is compressed, and the pipe walls are expanded slightly; section 1 now has slightly more water than before; section 2 therefore keeps on moving until section 1 is completely compressed; then the process of compression of section 2 occurs as with section 1. Continuing this process with successive sections, a pressure wave travels along the pipe toward the reservoir, and the entire kinetic energy of the water is transformed and used up in compressing the water and expanding the pipe walls.

(2). As soon as the last small section of water next to the reservoir has been compressed, it expands toward the reservoir; the pipe walls contract, and the section assumes its original form and pressure, but the velocity reverses toward the reservoir. Each section of water between the reservoir and the gate does this successively and the pressure becomes normal, with velocity toward the reservoir.

(3). The kinetic energy of the water column now moving toward the reservoir is expended in lowering the pressure in sections 1, 2, 3, etc. at the gate. The pressure falls below normal, and the water in the pipe comes to rest.

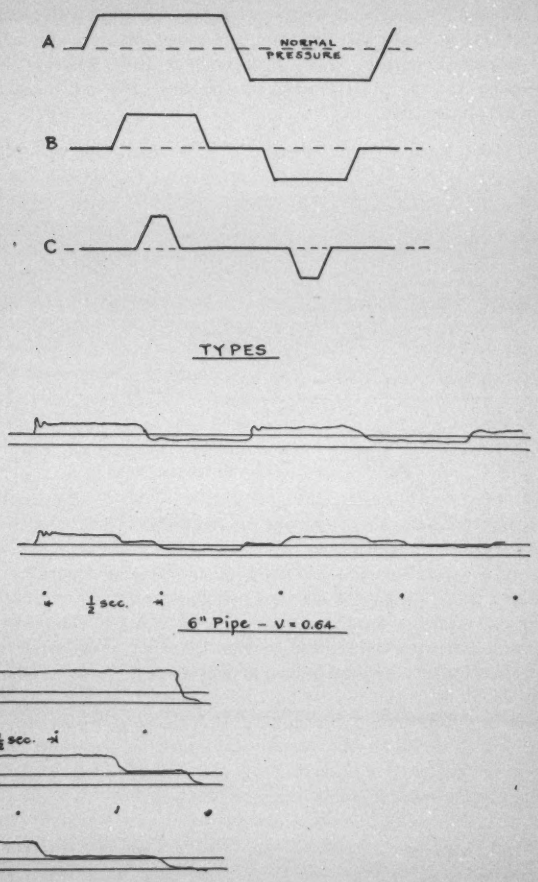


FIG. 2.— PRESSURE CURVES BY INDICATOR.

(4). Water from the reservoir enters the pipe; the nearest section resumes normal pressure and moves with its original velocity toward the gate. Finally all sections are in motion, water again reaches the gate with approximately its original velocity, and the same conditions prevail as at the beginning of the first period.

Without friction this phenomenon would continue indefinitely; actually the cycles recur with diminishing energy, and the pressure waves gradually die out.

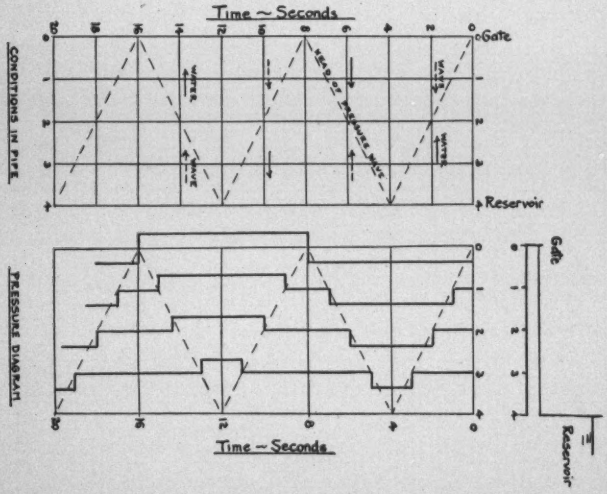


FIG. 3.— PRESSURE VARIATION DUE TO SUDDEN GATE CLOSURE.

Excess Pressure Head Due to Gate Closure. This may be determined by equating the kinetic energy of the moving water in the pipe line to the work done in compressing the water and expanding the pipe. The following formula* results:

$$h = \frac{145\,v}{\sqrt{1+\frac{Kd}{Et}}}, \text{ where}$$

h = maximum pressure rise in ft. due to gate closure.
v = velocity of water in pipe in ft. per sec.
K = bulk modulus of water (294 000 lb. per sq. in. or 42 400 000 lb. per sq. ft.).
E = modulus of elasticity of pipe walls.
$\frac{d}{t}$ = ratio of pipe diameter to thickness.

*For derivation of this formula see Barrows, *Water Power Engineering*, pp. 513–515.

In more useful form, the equation can be written as follows:

$$h = \frac{v_p\, v}{g}; \text{ where } v_p = \frac{4\,660}{\sqrt{1+\frac{Kd}{Et}}} = \text{the velocity of the pressure wave in ft. per sec.}$$

and $g = 32.2$ ft. per sec. per sec.

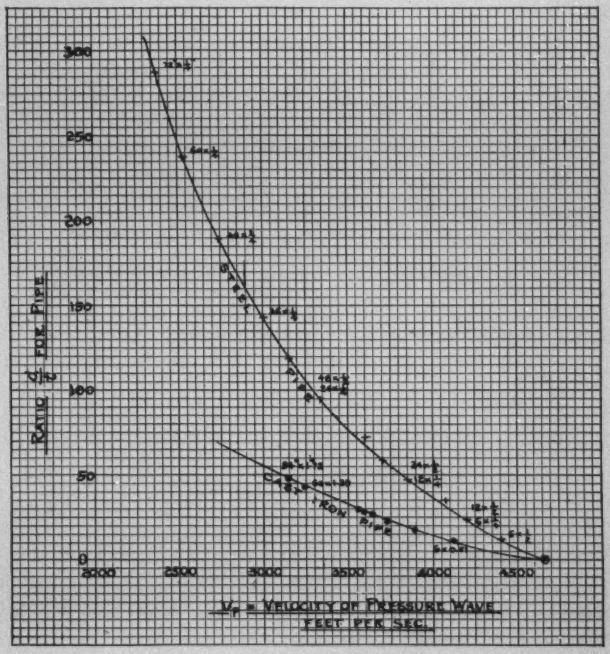


Fig. 4.— Velocity of Pressure Wave.

Velocity of Pressure Wave. In the formula for v_p, it will be noted that for a non-elastic pipe v_p becomes 4 660 ft. per sec., which is identical with the velocity of sound in water as determined by Korteveg.

The variation in v_p for different kinds of pipe is shown in Figure 4. As will be noted, v_p varies from about 3 000 to 4 500 ft. per sec. for cast-iron pipes and from about 2 500 to 4 500 ft. per sec. for steel pipes. For ordinary pipe lines, the range in excess pressure head due to sudden gate closure may, therefore, be written as follows:

$$\text{For cast-iron pipe: } h = \frac{v_p\, v}{g} = \frac{(3\,000 \text{ to } 4\,500)\, v}{32.2} = 95 \text{ to } 125\, v.$$

For steel pipe: $h = \frac{(2\,500 \text{ to } 4\,500)\ v}{32.2} = 80 \text{ to } 125\ v.$

Referring to Figure 4, a 48-in. steel pipe $\frac{1}{2}$ in. thick $\left(\frac{d}{t} = 96\right)$, for example, would have a value of $v_p = 3\,330$ and $\frac{v_p}{g} = 103$. The increase in pressure head for such a pipe due to sudden gate closure would be, as follows, for different velocities:

Velocity ft. per sec.	Increase in pressure head in ft.
1	103
2	206
3	309
4	412
5	515

Obviously, any increase in head due to sudden checking of any velocity, other than a relatively low one would be either destructive to the pipe or would greatly stress it. Sudden gate closures, therefore, must not be permitted.

Experimental Proof of Joukovsky's Theory. Joukovsky's theory checked excellently with the results of his experiments, as will be noted by referring to the accompanying table, in which are recorded the values obtained in one of his sets of experiments — *viz.*, for the 6-in. pipe. This pipe burst when a velocity of 7.5 ft. per sec. was suddenly checked a second time.

JOUKOVSKY'S EXPERIMENTS ON A 6-IN. PIPE — NOVEMBER 20, 1897.

No. of experiment.	Velocity of water in ft. per sec., v.	Duration of a round trip of wave in seconds.			Duration of gate closure in sec., T.	P in atmospheres.		
						From diagrams.		Calculated $P = 4\,v$.
		House I.	House II.	Average from a number of cycles.		House I.	House II.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	3.3	0.52	....	0.52	0.03	15.7	15.7	13.2
2	1.9	0.52	0.52	0.52	0.03	7.3	7.1	7.6
3	0.6	0.52	0.52	0.52	0.04	3.0	3.0	2.4
4	1.4	0.51	0.52	0.52	0.04	6.0	6.1	5.6
5	3.0	0.52	....	0.52	0.03	12.1	11.44	12.0
6	4.0	0.51	0.51	0.52	0.03	15.6	15.2	16.0
7	5.6	0.52	0.52	0.51	0.04	25.2	25.2	22.4
8	7.5	0.51	....	0.53	0.04	29.0	29.0	30.0
9	7.5	0.51	....	Pipe burst.	....	11.7	11.3	30.0

The length of the 6-in. pipe was 1 066 ft. The pressure wave made a round trip through this pipe in 0.52 sec.

Hence, the velocity of the pressure wave in a 6-in. pipe is

$$v_p = \frac{1\,066 \times 2}{0.52} = 4\,100 \text{ ft. per sec.}$$

The calculated value of v_p for a 6-in. pipe is 4 116 ft. per sec.

Effect of Dead Ends. Joukovsky also made experiments to determine pressure in a dead-end 2-in. pipe 517 ft. long, connected to his 4-in. pipe near the gate in the latter. (See Fig. 5.) He concluded and showed experimentally that due to reflection of the pressure wave from the dead end of the 2-in. pipe, excess pressures in the latter would be doubled and that if

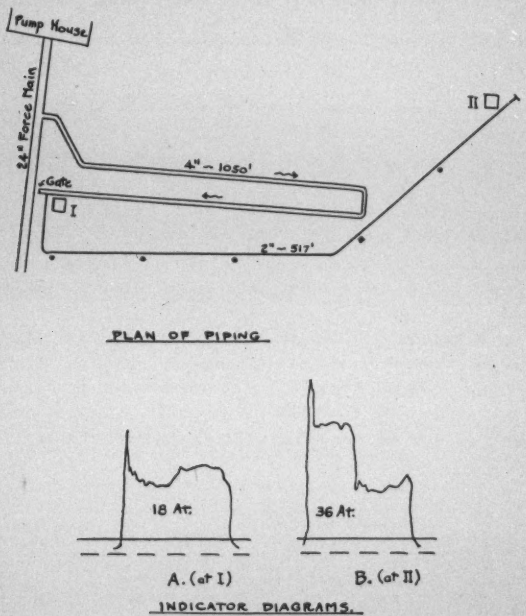


FIG. 5.— PRESSURES IN DEAD-END PIPE.

this occurred at a time when pressure in the larger pipe was supernormal, a very high pressure could result. A combination of dead-end pipes in a system might therefore cause reflection of pressures, to a dangerous extent.

Critical Time of Gate Closure. When a gate is closed slowly, each partial closure creates a pressure wave which travels to the reservoir and back in the time $T = \frac{2L}{v_p}$. Each small closure movement creates such a series of successive pressure waves.

Keeping in mind that the pressure at the gate is negative when the pressure wave returns, it will be seen that returning pressure waves will just balance the increase in pressure due to added gate movement. Pressure at the gate will, therefore, increase until the first return negative-pressure wave

reaches it $\left(T=\frac{v_p}{2L}\right)$, after which it will remain the same as long as the gate continues to be shut. Evidently, then, if the time of gate closure is less than or equal to $\frac{v_p}{2L}$, the same excess pressure will occur as when the gate is suddenly closed.

This "critical time," as it is called, is of great importance in preventing excessive pressure in penstocks of power developments due to quick closure of turbine gates by the governor. The time of action of the latter must be chosen well in excess of this critical time.

Pressures Due to Gate Closure in a Time Greater than the Critical Time. When the time of gate closure exceeds $T=\frac{v_p}{2L}$, the resulting excess pressures are much less than for quick closure. There is, however, much disagreement as to the formula for excess pressure under these circumstances.

Joukovsky concluded that for this condition the excess pressure would be

$$P'=P\times\frac{t_c}{t}, \text{ where}$$

P' = excess pressure head in ft. due to closure in time $t>\frac{2L}{v_p}$

P = excess pressure head in ft. for quick closure.

t = time of closure of gate (greater than t_c).

t_c = critical time of closure $=\frac{2L}{v_p}$.

It will be noted that by this method

$$h=\frac{v_p v}{g}\times\frac{2L}{v_p\times t}=\frac{2Lv}{gt}$$

and that h depends upon length of pipe line, original velocity of flow and time of closure of gate (t always $>t_c$).

Thus, for the 6-in. pipe and a velocity of 7.5 ft. per sec. in the preceding table, where t_c was 0.52 sec., the excess pressure heads would be as follows:

Values of t sec.	Excess pressure head ft.	Proportion of head of 960 ft. due to sudden closure.
1	495	0.52
2	247	0.26
5	97	0.10
10	52	0.05

This illustrates forcibly the great diminution in the water hammer effect of gate closure by increasing the time of closing.

Allievi, Johnson, Warren, Mead and others* have all deduced formulæ for the condition where t is greater than t_c. These in general give smaller results than the method proposed by Joukovsky, and it is likely, therefore, that his results are on the safe side.

*Warren, Penstock and Surge Tank Problems, *Trans. Am. Soc. C E.*, Vol. 79, pp. 238–305.

The need for further experimental work along this line to confirm the methods used is evident.

Practical Aspects of Water Hammer. It is evident from the foregoing discussion that, aside from conditions where it is possible to close a gate very quickly and where a very long pipe line is involved, there is commonly little possibility of destructive water hammer occurring.

To take an extreme case, namely a large steel pipe line 10 miles long and $v_p = 3\,000$, the critical time t_c would be $\frac{40 \times 5\,280}{3\,000} = 70$ sec., and it would

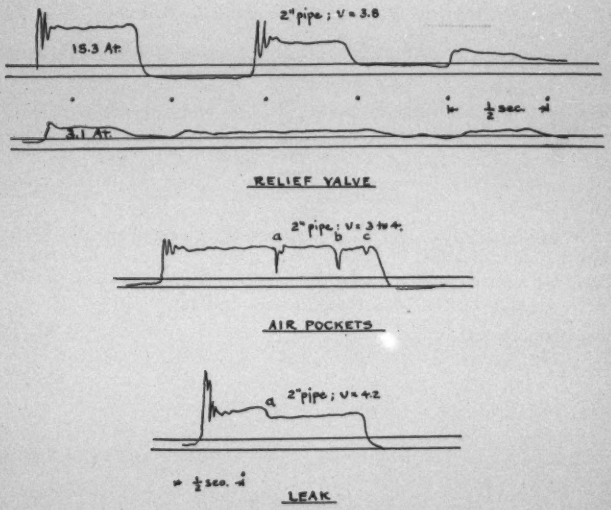


FIG. 6.— EFFECT OF RELIEF VALVES, AIR POCKETS AND LEAKS.

be unwise to permit gate closures in less than several minutes. A 5-mile line could, however, stand half this time with no greater excess pressures.

It would be of interest to hear experiences of water-works superintendents along this line — particularly in the case of breaks in pipe lines.

Joukovsky showed that the effects of water hammer due to quick gate closure could be rendered practically harmless either by the use of pressure-relief valves or air chambers. He developed a formula for determining the necessary size of air chamber for this purpose, but concluded that the use of relief valves was preferable because of the difficulty of keeping the necessary quantity of air in the air chamber.

In Figure 6 are shown pressure diagrams for his 2-in. pipe, the uppermost diagram without and the next lower one with a relief valve. As will

be noted, the excess pressure due to quick gate closure is reduced by the relief valve to one-fifth the amount obtained when no relief valve is used.

Joukovsky also pointed out two practical uses for the phenomena of water hammer. (1) For locating air pockets in pipe lines, the effect of which showed by a sudden drop and rise on the indicator diagrams. (See Fig. 6.) These points, marked a, b, c in Figure 6, were found to occur at a distance on the diagrams corresponding to that from the first increase in pressure to double the actual distance from the point where the diagram was taken. (2) For locating leaks in a pipe line, these showing upon the indicator diagram as a drop in the pressure line (at a, Fig. 6), which again is at a distance upon the diagram corresponding to double the distance between the gate and the point of leakage.

Gibson* has made use of the water hammer phenomenon in developing a method of measuring flow in penstocks of power developments, based upon time-pressure change curves due to turbine gate closure. While his method has been used in only a few cases, it appears to be accurate and of value where conditions permit its application.

Concluding. In preparing this paper the attempt has been made to state and explain the phenomenon of water hammer and its effects with as little technical detail as possible and to give such information regarding its action and effects as can readily be made use of by water-works officials. Acknowledgments are due especially to Miss Simin's paper in the *Jour. A.W.W.A.*, which is worthy of the most thorough study. It seems desirable also to again accentuate the need for further experimental work for the usual situation where time of gate closure is greater than the critical time.

*The Gibson method for measuring flow of water in closed conduits. *Jour. Am. Soc M.E.*, December, 1923, N. R. Gibson.

Discussion.

Arthur L. Shaw.* One case of water hammer with which water-works men commonly experience difficulty originates from conditions somewhat different from those used in the experiments outlined by Professor Barrows. When motor-driven pumps discharging into a long force main are suddenly stopped, a situation is created wherein the valve or other means of interrupting the flow, is not at the outlet end of the pipe as in Joukovsky's experiments, but at the opposite end. The valve in this case may be a check valve, a foot valve or one of several types of automatically-closing devices. Sudden stops may occur either accidentally, due to failure of power, or intentionally as when pumps are controlled by automatic apparatus such as float or pressure switches.

When a pump stops, the long column of water in the force main is free to continue moving ahead under its momentum, thereby producing an initial *reduction* of pressure at the pumps, until the column comes to rest and starts to travel in the reverse direction. It is the stopping of this reverse travel by the closure of the check or other valve which causes the water hammer most commonly experienced in pumping stations.

If the valve can be closed very quickly when a pump stops, *i.e.*, before any reverse flow has commenced, the increase of pressure due to the returning wave will be relatively small. For example, in the case of a pump drawing from a suction well and having a very quick-closing valve, the highest possible negative pressure which could be created due to the attempt of the column of water to continue in motion away from the pump would be that corresponding to a perfect vacuum, or about 34 ft., and it is unlikely that the returning wave of positive pressure will exceed that amount above normal. If, on the other hand, the closure of the valve is delayed, it will often be found that the head in the reservoir is sufficient to set up velocities in the reverse direction, back through the pump, considerably in excess of the velocities created by the pump during its operation, and the closing of the valve after such reverse flow has become established will then result in pressures comparable with the theory which Professor Barrows has described.

An illustration of the need for designing to meet accidental conditions as well as normal conditions recently occurred in connection with a large sewage pumping station where vertical-shaft pumps were operated automatically from float switches and discharged through about one mile of 54-in. force main. Solenoid-operated hydraulic butterfly valves were used instead of check valves and were intended to close before reverse flow could become established. When the station was first put into operation, the sticking of the solenoid mechanism caused a delay in the action of the butterfly, followed by quick closure after relatively high reverse-velocities

*Of Metcalf & Eddy, Engineers, Boston, Mass.

had been established. This caused water hammer greatly in excess of that contemplated in the design and resulted in the blowing out of joints in the pump-discharge header and the flooding of the pump well. Future difficulty in this instance has been avoided by the insertion of a tee in the discharge main, surmounted by a vertical air chamber, and by the more thorough anchorage of header piping.

JOHN F. SULLIVAN.* At Chicopee, we have a standpipe 130 ft. high and at the pumping station about 125 lb. per sq. in. pressure. Our power is supplied through the municipal station from the Turners Falls station. Quite often they pull the switch without notifying us. This leaves us without any power for our pump. The pump immediately shuts down and the check valve on the 20-in. line closes inside of a few seconds. This has happened at least five different times, and each time I have had one or two leaks in the line. I think that there is only one way to get rid of this trouble; that is by using a relief valve.

JOSEPH A. HOY.† We have a pumping station line that has been in service since 1911. There are a number of angles in the line. The pumping station is equipped with three centrifugal pumps. The difference in elevation between the station and the highest point, where one relief valve is placed, is practically 100 ft. During nineteen years of operation with three Ross valves we have never had any breakage on the main, although the pumps have been shut down and there is a 30-in. check on the line. Breakage has been restricted to branches and bends.

REEVES J. NEWSOM.‡ The Lexington, Ky. plant, which is one of our group, recently had occasion to construct a 20-in. line under emergency conditions to bring water from the Kentucky River to the city. Where the line left the river it went almost vertically up the side of a cliff for 300 ft. and then ran nearly level for some six miles. It was necessary to make three turns in this line as it came down the side of the cliff, two of which formed slight angles, and the third a right angle. There was a question as to what would happen when the pump shut down suddenly and the column of water, which would probably break near the top, because of the presence of air valves, would come backward down the hill. It might kick out one of these turns in the pipe line.

To obviate this danger we put in a check valve of special type. This valve has a spring, operating against the water pressure, so that immediately, when the velocity begins to slacken as a result of the shutting down of the pumps, the valve starts to close and does close without waiting for the column of water to come back and snap it shut. In addition to that, we placed a relief valve in the right angle turn in the line. This relief was set very delicately so that it would weep a little water whenever there was a small surge. We have had two shut-downs of the line due to the failure of electric power. Nothing happened, except that a small amount of water

*Superintendent of Water District, Chicopee, Mass.
†Foreman, Water Department, Worcester, Mass.
‡Vice-President, Community Water Service Co., New York, N. Y.

was lost through the relief valve. This installation shows that while this problem must be carefully handled it can be successfully solved by means of apparatus now on the market.

DAVID A. HEFFERNAN.* It has been my experience that some of the more modern plumbing equipment, such as flushometers, and other quick-closing valves, are the cause of complaints of excessive vibration and water hammer. Investigation usually shows that the main pipe running from the meter is inadequately supported and that there is no air chamber. It is my opinion that a great deal of this trouble can be eliminated, or at least lessened, by the installation of an air chamber on the house side of the meter, especially on large services.

HOWARD M. TURNER.†‡ Professor Barrows's paper describes the experiments on water hammer made by Joukovsky and his theory and formula for maximum water hammer obtained when a gate is closed instantaneously or within the critical time. He states, however, that in ordinary practise gates are not closed within the critical time so that the problem usually concerns a condition of slow closing. For this he gives Joukovsky's conclusions and formula and refers by name to several other formulæ, citing Warren's paper in the Transactions of the American Society of Civil Engineers.§ Since the publication in 1915 of Warren's paper, there have been several important contributions toward the solution of this problem to which reference should be made. A brief description of their contents may be of interest.

H. C. Vensano* in 1917 published the results of experiments on a long penstock and suggested as a formula the same as Joukovsky, $h = \frac{2Lv}{gt}$ as given by Professor Barrows but with the limitation that h could never be greater than $\frac{v_p v}{g}$.

In the discussion of that paper and in a subsequent paper▲ N. R. Gibson showed that any formula for water hammer with slow closing which did not take into account the normal head on the pipe was incorrect. This was also confirmed by R. D. Johnson, who had suggested the same thing previously in the discussion of Warren's paper. Gibson's paper followed the theory of the water hammer problem by Joukovsky, traced by arithmetic integration the waves of excess and sub-normal pressures back and forth between the gate and the reservoir for successive positions of a gate gradually closed and also derived a general formula which gave results that checked closely with the experiments previously published by Vensano.

In the discussion of this paper E. E. Halmos showed that L. Allievi,

*Superintendent of Water Works, Milton, Mass.
†Consulting Engineer, Boston, Mass., and Lecturer on Water Power Engineering, Harvard Engineering School, Cambridge, Mass.
‡By letter.
§Warren, Penstock and Surge Tank Problems — Trans. *Am. Soc. C. E.*, Vol. 79, pp. 238–305.
*Vensano, Pulsation in Pipe Lines as Shown by some Recent Tests — Trans. *Am. Soc. C. E.*, Vol. 82, p. 277.
▲Gibson, Pressures in Penstocks caused by the Gradual Closing of Turbine Gates, Trans. *Am. Soc. C. E.*, Vol. 83, pp. 707–775.

an Italian engineer, had previously proposed general formulæ which checked Gibson's results. Subsequently a translation* of Allievi's general theories of water hammer by Halmos was published. Allievi's first work appeared in Europe in 1902, and was followed by further work in 1913. He derives two parameters, one the "characteristic" of the pipe $\rho = \frac{v_p v}{2gY}$, where Y is the normal head on the pipe,— covering velocity, normal head and velocity of pressure wave of the pipe; the other the time of operation of the gate measured in periods of the critical time $\frac{2L}{v_p}$, $\theta = \frac{t v_p}{2L}$, and expresses the change of pressure during various motions by these two parameters. His method of solution permits of the plotting of graphs where in a Cartesian system of axes θ and ρ the water hammer for all possible conduits and all speeds of gate openings imaginable can be represented by curves, which give a simple means for solving all problems of this class.

The following table shows the water hammer for the example given by Professor Barrows figured from the Allievi curves for normal heads from 60 ft. to 400 ft.

Values of t sec.	Maximum excess pressure head ft. Joukovsky formula.	Maximum excess pressure head in ft. for different values of normal head by Allievi curves. Normal head in ft.			
		60	100	200	400
1	495	720	680	520	400
2	247	324	240	170	160
5	97	75	65	52	52
10	52	31	29	24	24

These solutions appear to include theoretically all the elements of the problem. As Professor Barrows says, additional experiments to confirm them will be of value.

*L. Allievi, General Theory of Water Hammer — Trans. by E. E. Halmos, M. *Am. Soc. C. E.*, Typography Riccardo Garroni, Rome, 1925.

was lost through the relief valve. This installation shows that while this problem must be carefully handled it can be successfully solved by means of apparatus now on the market.

DAVID A. HEFFERNAN.* It has been my experience that some of the more modern plumbing equipment, such as flushometers, and other quick-closing valves, are the cause of complaints of excessive vibration and water hammer. Investigation usually shows that the main pipe running from the meter is inadequately supported and that there is no air chamber. It is my opinion that a great deal of this trouble can be eliminated, or at least lessened, by the installation of an air chamber on the house side of the meter, especially on large services.

HOWARD M. TURNER.†‡ Professor Barrows's paper describes the experiments on water hammer made by Joukovsky and his theory and formula for maximum water hammer obtained when a gate is closed instantaneously or within the critical time. He states, however, that in ordinary practise gates are not closed within the critical time so that the problem usually concerns a condition of slow closing. For this he gives Joukovsky's conclusions and formula and refers by name to several other formulæ, citing Warren's paper in the Transactions of the American Society of Civil Engineers.§ Since the publication in 1915 of Warren's paper, there have been several important contributions toward the solution of this problem to which reference should be made. A brief description of their contents may be of interest.

H. C. Vensano* in 1917 published the results of experiments on a long penstock and suggested as a formula the same as Joukovsky, $h = \frac{2Lv}{gt}$ as given by Professor Barrows but with the limitation that h could never be greater than $\frac{v_p v}{g}$.

In the discussion of that paper and in a subsequent paper▲ N. R. Gibson showed that any formula for water hammer with slow closing which did not take into account the normal head on the pipe was incorrect. This was also confirmed by R. D. Johnson, who had suggested the same thing previously in the discussion of Warren's paper. Gibson's paper followed the theory of the water hammer problem by Joukovsky, traced by arithmetic integration the waves of excess and sub-normal pressures back and forth between the gate and the reservoir for successive positions of a gate gradually closed and also derived a general formula which gave results that checked closely with the experiments previously published by Vensano.

In the discussion of this paper E. E. Halmos showed that L. Allievi,

*Superintendent of Water Works, Milton, Mass.

†Consulting Engineer, Boston, Mass., and Lecturer on Water Power Engineering, Harvard Engineering School, Cambridge, Mass.

‡By letter.

§Warren, Penstock and Surge Tank Problems — Trans. *Am. Soc. C. E.*, Vol. 79, pp. 238–305.

*Vensano, Pulsation in Pipe Lines as Shown by some Recent Tests — Trans. *Am. Soc. C. E.*, Vol. 82, p. 277.

▲Gibson, Pressures in Penstocks caused by the Gradual Closing of Turbine Gates, Trans. *Am. Soc. C. E.*, Vol. 83, pp. 707–775.

an Italian engineer, had previously proposed general formulæ which checked Gibson's results. Subsequently a translation* of Allievi's general theories of water hammer by Halmos was published. Allievi's first work appeared in Europe in 1902, and was followed by further work in 1913. He derives two parameters, one the "characteristic" of the pipe $\rho = \frac{v_p\, v}{2g\, Y}$, where Y is the normal head on the pipe,— covering velocity, normal head and velocity of pressure wave of the pipe; the other the time of operation of the gate measured in periods of the critical time $\frac{2L}{v_p}$, $\theta = \frac{t\, v_p}{2L}$, and expresses the change of pressure during various motions by these two parameters. His method of solution permits of the plotting of graphs where in a Cartesian system of axes θ and ρ the water hammer for all possible conduits and all speeds of gate openings imaginable can be represented by curves, which give a simple means for solving all problems of this class.

The following table shows the water hammer for the example given by Professor Barrows figured from the Allievi curves for normal heads from 60 ft. to 400 ft.

Values of t sec.	Maximum excess pressure head ft. Joukovsky formula.	Maximum excess pressure head in ft. for different values of normal head by Allievi curves. Normal head in ft.			
		60	100	200	400
1	495	720	680	520	400
2	247	324	240	170	160
5	97	75	65	52	52
10	52	31	29	24	24

These solutions appear to include theoretically all the elements of the problem. As Professor Barrows says, additional experiments to confirm them will be of value.

*L. Allievi, General Theory of Water Hammer — Trans. by E. E. Halmos, M. *Am. Soc. C. E.*, Typography Riccardo Garroni, Rome, 1925.

PROCEEDINGS.

January Meeting.

Hotel Brunswick, Boston, Mass.

Wednesday, January 14, 1931.

President George H. Finneran in the Chair.

A paper, "Thawing Frozen Water Pipes" was read by President George H. Finneran. This paper was discussed by David A. Heffernan, Henry T. Gidley, S. A. Agnew, Roger W. Esty, Joseph A. Hoy, W. Guy Classon, Frank B. Northrop, John F. Sullivan, Reeves J. Newsom, Howard M. King, James W. Graham and Horace J. Cook.

A paper, "Water Hammer in Pipe Lines; Its Causes, Manner of Action and Effects," was read by H. K. Barrows, Consulting Engineer and Professor of Hydraulic Engineering, Massachusetts Institute of Technology. This paper was discussed by David A. Heffernan, Arthur L. Shaw, John F. Sullivan, Reeves J. Newsom, J. H. Hayes, Harry E. Holmes, Joseph A. Hoy and S. A. Agnew.

(*Adjourned.*)

February Meeting.

Hotel Brunswick, Boston, Mass.

Wednesday, February 11, 1931.

President George H. Finneran in the Chair.

Bills relating to the operation of water works under consideration by the Massachusetts legislature were called to the attention of the meeting by George A. King and were discussed by him and by Messrs. Stephen H. Taylor, Patrick Gear and Roger W. Esty.

A paper, "Items in the Operation of New York City's Water Supply System of Interest to the Superintendent," was read by William W. Brush, Chief Engineer, Bureau of Water Supply, Department of Water Supply, Gas and Electricity, New York City.

A discussion of the Massachusetts Water Lien Act was opened by James A. McMurray, Engineer in Charge, Income Branch, Water Service, city of Boston. Henry T. Gidley, David A. Heffernan, Patrick Gear, Walter E. Moore, Roger W. Esty, Mr. Delaney of Dudley, Stephen H. Taylor, J. Walter Ackermann and Horace Kingman took part in the discussion.

(*Adjourned.*)

GEORGE BOWERS.*

George Bowers, the son of Sewall and Sylvia (Fisher) Bowers, was born on October 30, 1848, in Middlesex Village, Lowell, then a part of Chelmsford, Massachusetts. His English ancestry is traced from Michael de Bures who was seated in Dorset, England, in 1075. His earliest paternal ancestor in America was George Bowers, whose son Jerathmel built the Bowers homestead in 1695 on land granted from the King of England. Mr. Bowers lived in this house many years, and the home still remains in the family, having passed down from generation to generation.

George Bowers' early education was that gained in the local schools of Middlesex Village and Lowell. He began his engineering work in the City Engineer's office in Lowell where he remained two years before entering the Massachusetts Institute of Technology with the class of 1875. After leaving the Institute he was employed as First Assistant Engineer on the construction of the Waltham Water Works.

Returning to Lowell he became First Assistant City Engineer and was elected City Engineer in 1887, a position which he filled for one year. He was reëlected City Engineer in 1891 and thereafter filled the office continuously till 1911.

Mr. Bowers' most notable work was that in providing the present water supply system of Lowell which remains as a monument to his memory. Recurrent outbreaks of typhoid fever were a menace so long as the city took its water from the Merrimac River. In 1893, as City Engineer, he carried on an extensive series of experiments with driven wells, which demonstrated the practicability of supplying Lowell with pure water from such source. In 1895, against strong political opposition, he succeeded in installing the present driven well supply at a time when Lowell was in the grip of a typhoid fever epidemic.

After retiring from the office of City Engineer, Mr. Bowers engaged in consulting engineering practice, particularly in the sanitary fields of water supply and disposal of wastes, in which he was specially qualified, because of the experience gained in his progressive municipal work for the city of Lowell. Among his clients were the town of Chelmsford, where he planned and supervised the construction of a new driven well water supply; and the Nashua Manufacturing Company and the American Hide and Leather Company, for both of which he handled problems of water supply and waste disposal.

During the latter part of his life Mr. Bowers was actively identified with the Lowell Institution for Savings. In this bank he was elected a Trustee, a Vice-President, and a member of the Board of Investment in

**Editor's Note.* Mr. Bowers died on February 28, 1930. This memoir is printed in the JOURNAL by permission of the *Journal of the Boston Society of Civil Engineers.*

1904, positions which he filled continuously until, at his death, he was First Vice-President and Chairman of the Board of Investment.

Mr. Bowers was elected a member of the Boston Society of Civil Engineers March 17, 1886, and served as a Director in 1908 and 1909. He became a member of the NEW ENGLAND WATER WORKS ASSOCIATION on March 9, 1892, and was President of that Association in 1905. He became a member of the American Society of Civil Engineers, October 1, 1902. He was a member of the Engineers Club of Boston, the Vesper Country Club, and several historical and philanthropic societies. All his life he was an active and devoted member of the Unitarian Church.

On October 24, 1878, Mr. Bowers married Estelle L. Wilkins, who survives him. He also leaves a daughter, Helen E. Bowers and two sons, George W. and Alton R. Bowers.

Ability, sterling worth, unflinching honesty, force of character, a kind heart and a companionable nature; these are some of the many qualities which won for George Bowers a wide circle of loyal friends. In his passing, the engineering profession has lost a valued member, and the city of Lowell an outstanding citizen.

FREDERICK H. FAY.

INDEX OF ADVERTISERS.

	Page
Ambursen Construction Co.	ii
Atlas Mineral Products Co.	xviii
Badger Meter Mfg. Co.	xv
Barbour, Frank A.	ii
Barrows, H. K.	ii
Biggs Boiler Works Co.	xxiv
Bingham & Taylor	v
Buffalo Meter Co.	x
Builders Iron Foundry	ix
Caldwell, Geo. A., Co.	xxxiv
Cement Lined Pipe Co.	xxvii
Central Foundry Co.	xix
Chapman Valve Mfg. Co.	xxxii
Clark, H. W., Co.	xxvii
Conard, William R.	ii
Darling Valve & Mfg. Co.	xxxvii
Donaldson Iron Co.	xxxiv
Eddy Valve Co.	xxxiii
Edson Manufacturing Co.	xl
Fairbanks-Morse & Co.	xxi
Fay, Spofford & Thorndike	ii
Ferullo, G., Co.	iii
Ford Meter Box Co.	xix
Fox, John, & Co.	xxvi
Fuller & McClintock	ii
Gamon Meter Co.	xiii
General Pipe Cleaning Co.	iii
Golden-Anderson Valve Specialty Co.	xxxi
Hayes Pump and Machinery Co.	xxx
Hays Mfg. Co.	xxxix
Hazen & Everett	ii
Hersey Mfg. Co.	iv
Houdlette, Fred A., & Son	xxvii
Hughes, Edward F.	iii
Hydraulic Development Co.	xxxvi
Kennedy Valve Mfg. Co.	xxix
Lead Lined Iron Pipe Co.	xxvi
Leadite Co.	Back cover
Lock Joint Pipe Co.	Facing front cover
Ludlow Valve Mfg. Co.	xxxviii
Main, Charles T., Inc.	ii
Main, M. B.	xxv
Marsur, F. A., & Co.	xvii
McWane Cast Iron Pipe Company	xxv
Metcalf & Eddy	ii
Mueller Co.	xvi
Murray Iron Works Co.	xx
National-Boston Lead Co.	xxxv
National Meter Co.	xiv
National Water Main Cleaning Co.	xxx
Neptune Meter Co.	vi
New England Water Works Association	xxvi
Pirnie, Malcolm	iii
Pierce-Perry Co.	xxvii
Pitometer Company	iii
Pittsburgh Equitable Meter Co.	vii
Rensselaer Valve Co.	xxv
Ross Valve Mfg. Co.	xxx
Simplex Valve & Meter Co.	xii
Smith, The A. P., Mfg. Co.	xix
Starkweather & Broadhurst	xix
Sumner & Dunbar	xxvii
Symonds, Henry A.	iii
Thorpe, Lewis D.	iii
Turbine Equipment Co.	xxii
Union Water Meter Co.	xi
U. S. Cast Iron Pipe and Foundry Co.	Facing back cover
Wallace & Tiernan	xxiii
Warren Foundry and Pipe Co.	xlv
Weston & Sampson	ii
Wood, R. D., & Co.	xxviii
Worthington Pump and Machinery Corp.	viii

(Classified index on page xli)

ENGINEERS' SECTION

FULLER & McCLINTOCK
Engineers

NEW YORK, 170 Broadway

Philadelphia, Pa., Pennsylvania Bldg. 15th and Chestnut Streets
Kansas City, Mo., Waldx Bldg. 600 Walnut Street

H. K. BARROWS
M. Am. Soc. C. E.
Consulting Hydraulic Engineer

Water Power, Water Supply, Sewerage, Drainage. Investigation Reports, Valuations, Designs, Supervision of Construction

BOSTON, MASS. 6 BEACON ST.

WILLIAM R. CONARD
Amer. Soc. C. E. Amer. Soc. M. E. A. S. T. M.

321 High St., Burlington, N. J.

Inspections and Tests of Materials

Reports Designs Specifications

WESTON & SAMPSON
Consulting Engineers
Robert Spurr Weston George A. Sampson

Water Supply and Sewerage
Chemical and Bacteriological Laboratory

14 BEACON ST. - BOSTON, MASS.

FAY, SPOFFORD & THORNDIKE
Consulting Engineers

Investigations Reports Designs
Engineering Supervision Valuations

Port Developments Industrial Plants
Bridges Buildings Foundations

Water and Sewerage Works

44 SCHOOL STREET BOSTON

HAZEN & EVERETT
Civil Engineers
C. M. EVERETT L. N. BABBITT

WATER WORKS
Design Construction Operation
Valuations Rates

25 West 43rd Street = New York City

METCALF & EDDY
ENGINEERS
Harrison P. Eddy — John P. Wentworth
Charles W. Sherman — Harrison P. Eddy, Jr.
Almon L. Fales — Arthur L. Shaw
Frank A. Marston — E. Sherman Chase

Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Laboratory Valuations
STATLER BUILDING BOSTON

FRANK A. BARBOUR
Consulting Engineer

Water Supply, Water Purification, Sewerage and Sewage Disposal.

Tremont Building, Boston, Mass.

CHAS. T. MAIN, INC.
ENGINEERS

Industrial Buildings
Electrical, Steam and Hydraulic Power
Valuations and Reports
Consulting Engineering

201 Devonshire St. Boston, Mass.

AMBURSEN DAMS
Hydroelectric Developments
Water Supply and Irrigation Dams
DAMS ON DIFFICULT FOUNDATIONS
AMBURSEN CONSTRUCTION CO.
Incorporated
Room 2520, Grand Central Terminal Bldg., New York
Kansas City, Mo. Atlanta, Ga.

HENRY A. SYMONDS
Consulting Engineer
70 State St., Boston, Mass.
WATER SUPPLY
Surveys — Estimates — Designs
Supervision
MANAGEMENT AND ORGANIZATION
EFFICIENCY REPORTS

LEWIS D. THORPE
Civil and Sanitary Engineer
Water Works, Sewerage and Sewage Disposal
Supervision of Construction and Operation
6 Beacon Street
BOSTON, MASS.

MALCOLM PIRNIE
ENGINEER
Malcolm Pirnie Charles F. Ruff
Water Supply, Treatment, Sewerage
Reports, Plans, Estimates,
Supervision and Operation,
Valuation and Rates.
25 W. 43rd Street New York, N. Y.

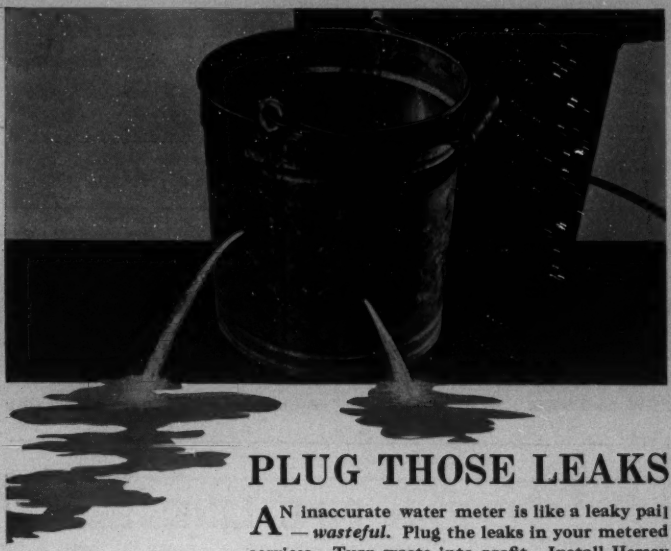
THE PITOMETER COMPANY
ENGINEERS
Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Penstock Gaugings
50 Church Street New York City

CLEAN PIPE LINES
having high coefficients deliver more water and give better fire protection than corroded mains.
High coefficients mean greater delivery in gravity mains and lower power costs in pumping mains.
GENERAL PIPE CLEANING COMPANY
Commercial Trust Bldg. Philadelphia, Pa.

CONTRACTORS

G. FERULLO COMPANY
General Contractors
Specializing in Water Works
31 NORTH SQUARE
BOSTON, MASS.
Telephone, Richmond 1200

EDWARD F. HUGHES
Water Works Contractor
Public and Private Water Supply
Artesian and Driven Wells
Foundation Borings
53 State St. Room 1102 Boston



PLUG THOSE LEAKS

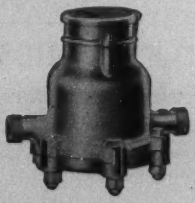
AN inaccurate water meter is like a leaky pail — *wasteful.* Plug the leaks in your metered services. Turn waste into profit. Install Hersey Meters. They maintain their initial registration accuracy over a period of many years. They plug the leaks in municipal finances that go with the use of less accurate meters.

In the Hersey Meter the disc piston is perfectly balanced. No guides that introduce friction and wear and detract from accuracy are necessary. Perfect balance assures extreme sensitivity. Streams as small as 1-32 of an inch are accurately registered. Rigid testing is enforced in the Hersey Plant. Hersey inspectors discard all parts not within a ten-thousandth of an inch limit.

For *accurate* meters that will return just revenue, write the nearest Hersey Branch Office. An engineer there will gladly specify for you.

THE HERSEY DISC METER

Strength, Accuracy, Diptinning, and Balance make this meter your best investment.



HERSEY WATER METERS

HERSEY MANUFACTURING COMPANY, *Main Office and Works:* Corner E and 2nd Sts., South Boston, Mass. *Branch Offices:* NEW YORK CITY, 290 Broadway; PORTLAND, ORE., 475 Hoyt Street; PHILADELPHIA, PA., 314 Commercial Trust Bldg.; ATLANTA, GA., 510 Haas-Howell Bldg.; DALLAS, TEX., 402 Praetorian Bldg.; CHICAGO, ILL., 10 So. LaSalle Street; SAN FRANCISCO, CAL., 690 Market Street; LOS ANGELES, CAL., 450 East Third Street.

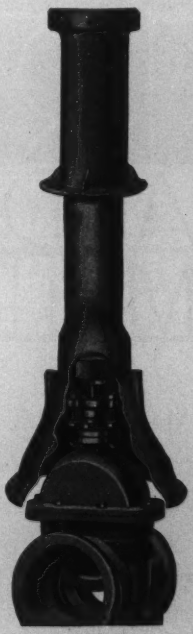
BINGHAM & TAYLOR'S Sliding Type Service and Valve Boxes are meeting with the approval of many New England Waterworks officials.

The cuts shown are our two and three piece sliding type adjustable valve boxes.

The flange on the bottom of the top section can be located any distance from the top.

We carry a complete stock on hand at all times.

Wire, phone or write us when you are in a hurry for a shipment.



ESTABLISHED 1849

B AND T

Bingham and Taylor Corporation

MANUFACTURERS

575-601 Howard Street . . Buffalo, N. Y.

NOW NEARLY 5¾ MILLION TRIDENT AND LAMBERT METERS

Made and sold the world over. And this figure is conservative. Truly, "Cash Registers of the Water Works Field."

"Pioneers in Meter Progress
Yesterday TODAY Tomorrow"

NEPTUNE METER CO.

THOMSON METER CORPORATION

50 EAST 42ND STREET
NEW YORK CITY, N. Y.

Neptune Meter Co., Ltd.
Toronto, Ont.

PITTSBURGH EQUITABLE METER COMPANY

Main Offices and Factories — Pittsburgh, Pa.

New York	Dallas	Los Angeles	Seattle	Chicago
Tulsa	Salt Lake City	Houston	Davenport	Columbia
		Kansas City		

WORTHINGTON PRODUCTS

PUMPS
All Sizes . . . All Types . . . For All Services
Any Capacity . . . Any Pressure

—

COMPRESSORS
Stationary and Portable

—

CONDENSERS
and Auxiliaries

—

DIESEL ENGINES

—

GAS ENGINES

—

FEEDWATER HEATERS

—

WATER, OIL and GASOLINE METERS

—

MULTI-V-DRIVES

—

ROCK DRILLS

—

AUTOMATIC HEAT TREATING MACHINES
FOR DRILL STEEL

—

FORGING FURNACES
FOR DRILL STEEL

—

DRILL STEEL
AND ACCESSORIES

—

CHROMIUM PLATING

—

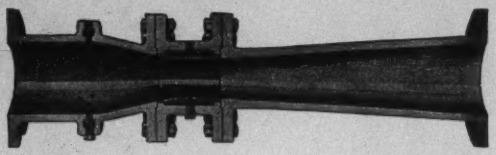
Literature on request

WORTHINGTON PUMP AND MACHINERY CORPORATION
Works: Harrison, N. J. Cincinnati, Ohio Buffalo, N.Y. Holyoke, Mass.
Executive Offices: 2 Park Avenue, New York, N.Y
GENERAL OFFICES: HARRISON, N. J
District Sales Offices and Representatives:

ATLANTA	CHICAGO	DALLAS	EL PASO	LOS ANGELES	PHILADELPHIA	ST. PAUL	SEATTLE
BOSTON	CINCINNATI	DENVER	HOUSTON	NEW ORLEANS	PITTSBURGH	SALT LAKE CITY	TULSA
BUFFALO	CLEVELAND	DETROIT	KANSAS CITY	NEW YORK	ST. LOUIS	SAN FRANCISCO	WASHINGTON

Branch Offices or Representatives in Principal Cities of all Foreign Countries G-44

WORTHINGTON



The Venturi Tube

In 1891 the Venturi Tube was new. Those Engineers who knew of it hoped it would help solve the difficult problem of measuring the flow of water in large pipe lines.

In 1931 the Venturi Tube is accepted by Engineers as the most dependable and accurate means of measuring flow through pipe lines.

It may be worthwhile, however, to summarize a few of the important advantages of the Venturi Tube:

1. The flow is guided at all points.
2. The inlet and throat pressures are taken off at definitely fixed points; the annular pressure chambers assure the use of true average pressures.
3. The Venturi throat is accurately centered in relation to the rest of the pipe line.
4. The friction loss through a Venturi Tube is the lowest of any differential producer. The Venturi Meter, then, operates on a greater differential with less friction loss, and is a more powerful instrument with a wider measuring range than other meters.
5. The coefficients of the Venturi Tube have been definitely established in numerous calibration tests of tubes ranging in size from 1 inch to 8 feet in diameter.

VENTURI
"VENTURI" Registered

BUILDERS IRON FOUNDRY

"Builders of the Venturi since 1891"

9 Codding Street Providence, R. I.

FEW PARTS
EASY to REPAIR
.. that's what I like about Niagara Meters

Otto Parsons, Supt.
Painsville Waterworks
Painsville, Ohio

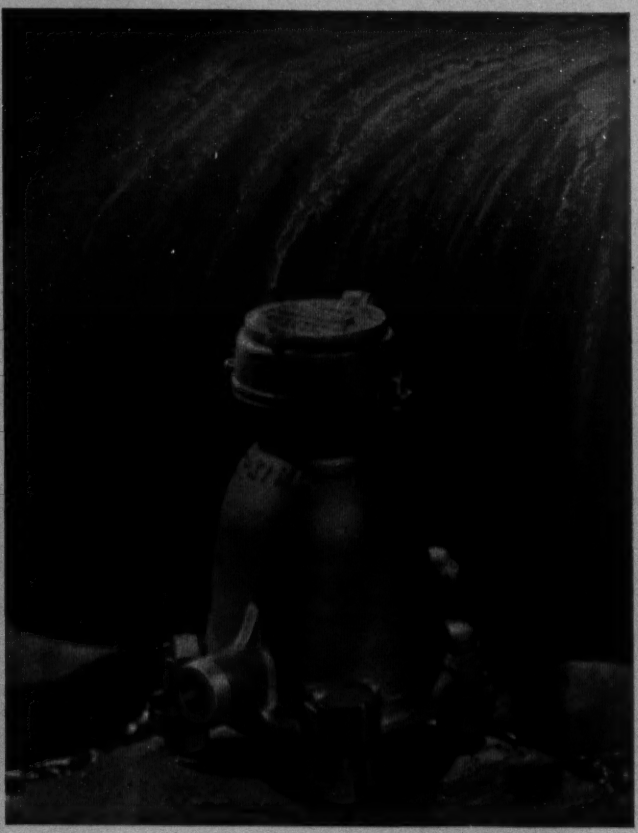
PAINSVILLE, Ohio Waterworks has been using Niagara Meters since 1893—thirty-eight years! Mr. Otto Parsons, Superintendent, recently told a Buffalo Meter Company representative that the reason he likes Niagara Meters is because of their few parts, ease of repairs and low maintenance cost.

Because of the simplicity of construction and the correct application of engineering principles, Niagara and American Water Meters are everywhere meeting the exacting tests of time. When it is necessary to make repairs the cost of repair parts is extremely nominal.

Before you install water meters in your municipality, look at the long and favorable records behind Niagara and American Water Meters. This is your assurance that your city will get the most for its money.

NIAGARA (IRON CASE) and AMERICAN (BRONZE CASE)
Water Meters

BUFFALO METER CO.
2889 Main St. Buffalo, N. Y.



Constant as the flowing waters— Union Water Meter

Union Water Meter Co., Worcester, Mass.

Incorporated 1868

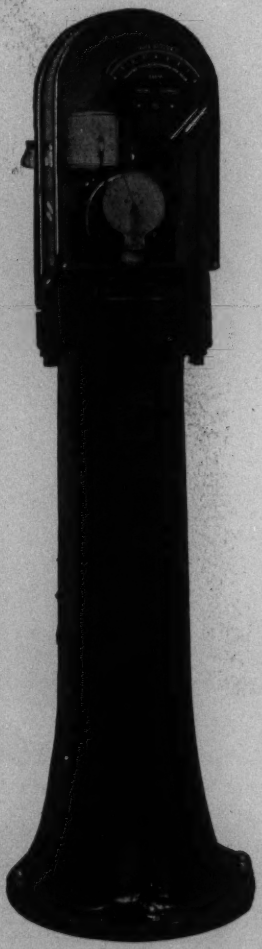
New York: 50 Church St. Philadelphia: 424 Bulletin Bldg.

UNION

Water Meters
Pressure Regulators

Chronometer Valves
Presses for Lining Pipe

Easy Turning Stops
Alarm Signals



SIMPLEX
VENTURI TYPE
METERS

Indicate the flow on a uniformly graduated dial.

Record the flow on a rectangular chart with uniform graduations.

Totalize the flow on a five-dial totalizer, so designed that the last figure can be read with accuracy on a much larger scale.

They may be furnished for floor stand, wall bracket or panel mounting.

May be used for pump discharge — gravity supply — in the Filter Plant — or Sewage Treatment Works.

Simplex Meter Registers may be checked at any time while in service by use of apparatus furnished as standard equipment — an exclusive feature of the Simplex Meter.

Simplex Meters are the choice of many who value quality and accuracy above initial cost.

Write for data.

Simplex Valve and Meter Co.

6757 Upland St., Philadelphia, Pa.

"WATCH DOG" WATER METERS

ACCURATE *DURABLE*

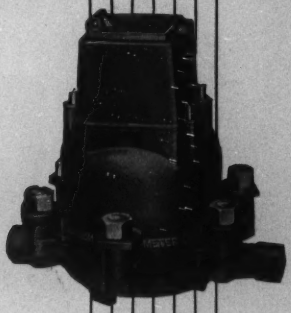
DISC, CURRENT AND COMPOUND TYPES

Inquiries Solicited

GAMON METER COMPANY

NEWARK NEW JERSEY

METERS



The NASH

View it with a Critic's Eye

From the heavy bronze casing down to the smallest screw, you will find the NASH meeting every meter expectation you may have in mind. The intermediate is strong, the disc perfectly balanced, the register excellent. And the NASH has a frost protection feature that beats them all for simplicity and economy,—a breakable flange washer,—always effective, easy to use, and costing almost nothing. Why not get a sample NASH and examine it?

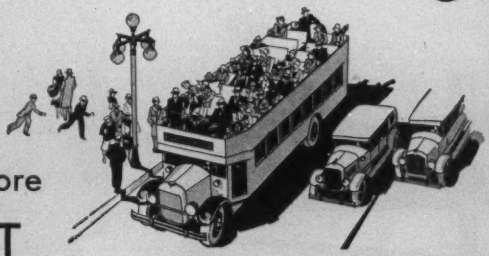
NATIONAL METER CO.

299 Broadway, New York

New England Office:
368 Congress Street, Boston

Chicago Cincinnati Atlanta
San Francisco Los Angeles

CAPACITY COUNTS



There's more

PROFIT

in the upper deck!

Boulevards would not be dotted with double decked busses unless that extra capacity was profitable . . . Likewise Badger Water Meters would not boast of larger capacities, unless large capacities were desirable in meters.

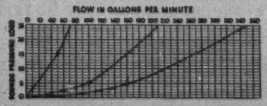
All Badger Disc Meters, size for size, have the largest capacities with the least absorption of pressure . . . and they are especially sensitive and accurate on small streams as well as maximum capacity flows.

Check the chart below . . . it proves Badger capacity.

BADGER METER MFG. CO.
Milwaukee, Wisconsin

Branch Offices In

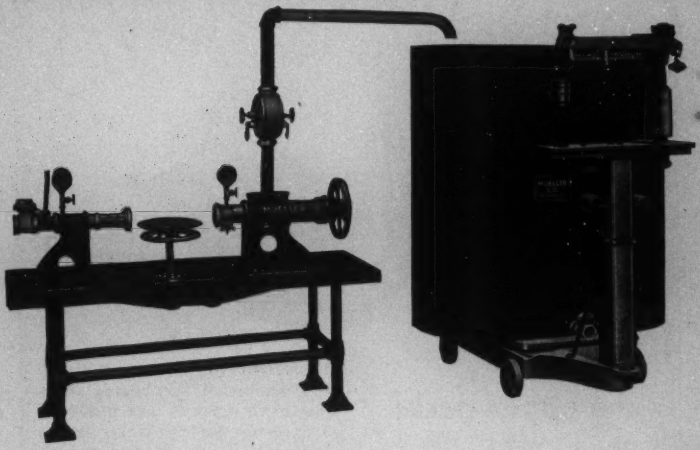
New York City	Seattle, Wash.	Savannah, Ga.
Chicago, Ill.	Cincinnati, O.	Los Angeles, Cal.
Waco, Texas	Kansas City, Mo.	Philadelphia, Pa.



● indicates minimum capacity at which a 25 pound pressure loss is allowed by A.W.W.A. Standard.

BADGER Water METERS

Assures full revenue



NO longer need there be any question as to whether or not you are getting full water supply revenue. Under and over-registering meters, with their consequent unfairness to all people concerned, are now a thing of the past.

The Mueller Water Meter Tester, designed and built by the 72-year old Mueller Company enables you to know *before* installation that your meter is working accurately.

These machines test standard size meters quickly and accurately, singly or in gangs. Special fittings accommodate meters up to 12 inches.

Check this waste in your water works now! Remember that Mueller Water Meter Testers soon pay for themselves by eliminating revenue losses. Write us for complete information on this necessary measure for economy in your 1931 budget.

MUELLER CO. (Established 1857), Decatur, Illinois. *Branches:* New York, Dallas, Atlanta, San Francisco, Los Angeles, Chicago. *Canadian Factory:* MUELLER, Limited, Sarnia.

MUELLER

PLUMBING BRONZE AND VITREOUS WARE

ATTENTION
WATER WORKS
OF NEW ENGLAND

A few reasons why we solicit your inquiries on Water-Works Pumping Equipment:

First. — We make a specialty of furnishing Complete Water-Works Pumping Units of all types.

Second. — Total responsibility of installation is assumed by us.

Third. — We relieve the purchaser of every detail and turn the complete unit over to him under actual operation and with guarantee.

Fourth. — Every unit installed to date has exceeded its guarantee and has been completely accepted.

Remodeled Pumping Station at Bridgewater, Mass., completely installed by F. A. Mazzur Co., Inc. Barbour & Dixon, Eng'r's.

F. A. Mazzur Co., Inc.
141 MILK STREET, BOSTON

MINERALEAD

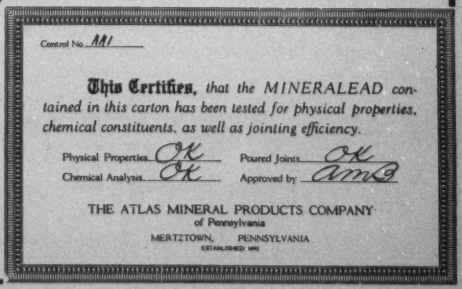
A PROVEN JOINTING MATERIAL FOR WATER MAINS

ABSOLUTE UNIFORMITY

Easy Melting
Rapid Pouring
No Caulking
Tighter Joints
No Radial Cracks

Is checked systematically to insure perfect performance.

Write for Catalogue


Control No. AA1
This Certifies, that the MINERALEAD contained in this carton has been tested for physical properties, chemical constituents, as well as jointing efficiency.
Physical Properties OK
Poured Joints OK
Chemical Analysis OK
Approved by AMG
THE ATLAS MINERAL PRODUCTS COMPANY
of Pennsylvania
MERTZTOWN, PENNSYLVANIA
ESTABLISHED 1892

New England Distributor
FRED R. HOUDLETTE & SON, INC.
40 Central Street
Boston, Mass.

STARKWEATHER & BROADHURST
INCORPORATED

Engineers and Contractors for
Water Works and Sewage Pumping Plants

79 MILK STREET, BOSTON HANcock 4530

UNIVERSAL CAST IRON PIPE

The Central Foundry Company
Graybar Building, 420 Lexington Ave.
NEW YORK CITY

CHICAGO 332 S. Michigan Ave.
BIRMINGHAM Comer Bldg.
DALLAS Praetorian Bldg.
SAN FRANCISCO Rialto Bldg.

VALVES PLACED UNDER FULL PRESSURE

LET the ol' water slide through the line the same as ever! The Smith Valve-Inserting Machine will place that much-wanted valve for you without trouble, without loss of time or water, and economically. It will look like the above view when the job is completed. These machines are standard equipment in most waterworks departments. They may be had to handle insertions from 4" to 30" diam. inclusively.

SMITH
WATER WORKS SPECIALTIES & SUPPLIES
THE A.P. SMITH MFG. CO. *East Orange, N.J.*

NOW! the TYPE X

A Real Convenience In Meter Box Covers

WITH the Type X Meter Box Cover, the lid is unlocked with the Ford Worm Lock which *lifts the lid and breaks the seal of ice or dirt.* Then the lid is slid forward to a stop and leaned back.

Hinge effect is obtained *without openings* in lid. *No mud, snow or leaves dragged into the box. Only one hand needed* in opening or closing meter box.

Write for Literature and Prices.

Notice neat appearance.

Simply slide lid forward and lean back.

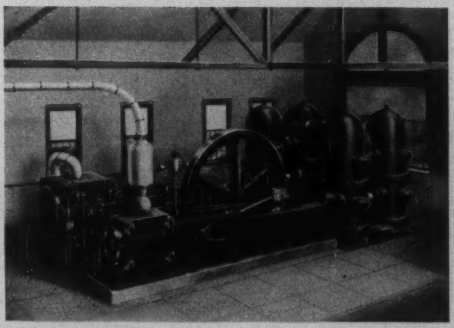
The FORD METER BOX CO.
WABASH, INDIANA
WATER METER SETTING & TESTING EQUIPMENT

MURRAY IRON WORKS CO.

(INCORPORATED 1870)

BURLINGTON, IOWA, U. S. A.

Builders of High Duty Pumping Engines

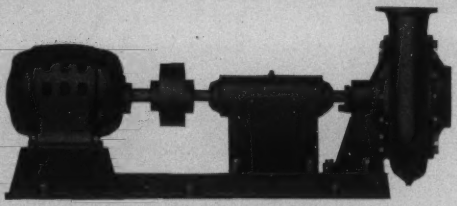


Murray High Duty Crank and Fly Wheel Pumping Engine, Opposed Type

STARKWEATHER & BROADHURST, INC.,
79 MILK STREET, BOSTON

will be glad to show you the superior design and excellent workmanship of the new 3 M. G. D. Murray Pump in the Arlington Pumping Station of the Metropolitan District Commission. Exceptional operating results are being obtained as shown by the official duty test which exceeded the guaranty by a substantial amount.

PLEASE SEND US YOUR SPECIFICATIONS AND CALLS FOR BIDS



Fairbanks-Morse Horizontal Trash Pump direct-connected to Fairbanks-Morse Ball-Bearing Motor

Now a great advance in sewage pumping

For the first time a pump has been designed that will handle fluids containing the fibrous and stringy matter found in sewage — without clogging, without preliminary screening, and without the excessive power consumption that characterizes the less satisfactory open impeller type of pump.

The secret of this pump's success lies in the design of the simple two-blade impeller. The blades of the impeller have well-rounded entering ends and are well filleted with the shrouds or sides. Thus a rag or other trash does not find sharp projections on which to catch and cause clogging. Since the impeller is the enclosed type, foreign matter, in passing through, does not come into contact with stationary side plates, but is promptly discharged through one of the large ports into the pump case. In this way power is conserved and efficiency increased.

This pump was designed by Mr. A. B. Wood who has been serving the city of New Orleans and other municipalities in the capacity of consulting engineer. It was originated by Mr. Wood to cope with the very unusual sewage problems found in New Orleans and met with immediate success.

Fairbanks-Morse Trash Pumps are made in two types, horizontal and vertical. They are ruggedly built to cope with severe service and at the same time they possess such refinements as ball bearings, smoothed fluid passages, and other marks of quality construction.

Ask for bulletins giving complete details.

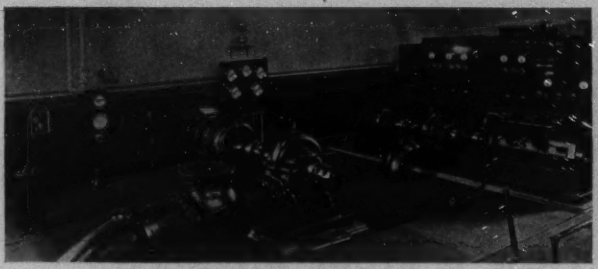
FAIRBANKS, MORSE & CO., Chicago

28 branches in principal cities at your service.

FAIRBANKS-MORSE

PUMPS · DIESEL ENGINES · MOTORS

100% DE LAVAL



WALNUT STREET PUMPING STATION
LYNN, MASS.

For 17 years DE LAVAL PUMPS have supplied water to the residents of the City of Lynn. From an initial installation in 1914 of *one* steam turbine driven high and low service unit of 15 M.G.D. capacity the number of DE LAVAL PUMPS operated by this City has increased to *seven units* having a total capacity of 86 M.G.D.

The 14 M.G.D. single stage low service pump, and the 2 M.G.D. two-stage combination gasoline-electric unit shown in the photograph, were placed in operation in January, 1930.

Surely the record speaks for itself—Dependable and efficient service.

TURBINE EQUIPMENT COMPANY
OF NEW ENGLAND
80 Federal Street, Boston Phone LIBerty 5993

New England Representative for
DE LAVAL STEAM TURBINE COMPANY
Trenton, N. J.

327 VACUUM CHLORINATORS

Seven W&T solution feed VACUUM CHLORINATORS (Type ASV) on the LOS ANGELES, Calif. Water Supply

FIFTY three cities are on the American Medical Association Honor Roll. Fifty three cities with a typhoid death rate of less than two per hundred thousand—and chlorination played a vital part in making this splendid record.

But—the significant fact is this—327 W & T Solution Feed VACUUM CHLORINATORS are sterilizing the water supplies, disinfecting the swimming pools, chlorinating the sewage in these justly honored fifty three American municipalities.

Three thousand Solution Feed VACUUM CHLORINATORS are now in daily service.

Their ease of operation, their low maintenance costs have been proven. Their absolute dependability is attested by the record of these 327 machines.

NO VACUUM CHLORINATOR HAS EVER WORN OUT

Ask for Technical Publication 38

WALLACE & TIERNAN CO., INC.
Manufacturers of Chlorine Control Apparatus
NEWARK, N. J.
BRANCHES IN PRINCIPAL CITIES

A Product of

WALLACE & TIERNAN

"The only safe water is a sterilized water"

SA-36

The Melrose Construction Company of New York City making a difficult installation, using 36-inch Biggs electrically welded steel pipe for the Department of Water Supply, Gas, and Electricity, New York City. Many special sections necessitated accurate shop fabrication. "It has been a pleasure to do business with your company", writes Joseph Burns, Melrose president.

Another

Biggs Welded Steel Pipe Line Is Installed in New York City

WATER-WORKS engineers everywhere are placing more and more steel pipe in the ground each year because of: 1. Its dependability. 2. Its long life. 3. Its superior structural strength and ductility over all other types. 4. Its low first cost and maintenance. 5. The continuity of service and freedom from rupture which it assures.

Biggs Electrically Welded Steel Pipe represents that medium at its best, because: 1. It is manufactured under a welding procedure which controls all variables and predetermines definite results. 2. Its 100% joint efficiency has been assured by countless bend, tension, torsion, and hydrostatic tests which are impossible with any other type of steel pipe and which have clearly demonstrated that the Biggs weld is stronger than the plate itself. 3. Its smooth interior yields a maximum carrying capacity with an average "C" of 139. 4. The seams are welded automatically from both sides, producing a uniform, flexible, balanced weld. 5. It is furnished in long lengths — from 30 to 36 feet without intermediate seams.

Data will be cheerfully furnished upon request.

THE BIGGS BOILER WORKS COMPANY, AKRON, OHIO

New York Detroit

BIGGS Steel Pipe *Riveted and Welded*

The Biggs Boiler Works Co. Akron Ohio

CAST IRON PIPE

Bell and Spigot—Sand Cast—Modern Weights

Sizes: 1¼ through 12 inches. Lengths to 16 feet

Boston stocks. Furnished with or without Precalked Joints

McWane Cast Iron Pipe Company

Eastern Office: 123 South Broad Street Philadelphia

Sales Representatives:
FRED A. HOUDLETTE & SON
40 Central Street, Boston
Eastern Mass., Me., N. H.

General Offices: BIRMINGHAM, ALA.
Foundries: BIRMINGHAM, ALA., PROVO, UTAH

Main's Hotcoating for the inside of standpipes and water tanks, will stop all pitting and corroding, and is guaranteed for seven years.

Also

Main's Coverall Salt Air Paint, for the outside of standpipes and water tanks, guaranteed for four years.

M. B. MAIN **Box 189, Somers Point, N. J.**

The "COREY" Hydrant

Why you should use GENUINE COREY HYDRANTS

Water to Nozzles quicker than other Hydrants.

Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

Nozzles screwed in — not leaded.

Can be lengthened without shutting off water.

Will not flood if broken.

Positive Drip — cannot freeze.

Standpipe can be revolved quarter turns — Nozzles always in right direction.

Write for copy of our new Catalog "G."

CHARLES L. BROWN,
New England Sales Manager, Lock Box 2, Northboro, Mass.

RENSSELAER VALVE COMPANY
TROY, N. Y.

New England Water Works Association

Specifications, Forms, and Meter Rate Sheets

Standard Specifications for Cast-iron Pipe and Special Castings, per copy,		$0.25
Forms for Slow-sand Filtration Plants	per set,	0.30
Forms for Rapid-sand Filtration Plants	per set,	0.30
Meter Rate Sheets: Single sheet		0.05
100 sheets, in orange		2.50
100 sheets, in black		2.25

NICHOLAS ENGEL

JOHN FOX & CO.

CAST IRON

WATER & GAS PIPES

FLANGE PIPE

Special Castings, Fire Hydrants, Valves

General Foundry and Machine Work

WOOLWORTH BUILDING 233 BROADWAY

NEW YORK CITY

HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments

use

LEAD-LINED IRON and TIN-LINED PIPES

for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

Wakefield Mass.

PIERCE-PERRY CO.

SUCCESSORS TO
GEORGE E. GILCHRIST CO.
WHOLESALERS OF

Steel, Wrought Iron, Brass Pipe and Water Works Materials of all kinds including copper service pipe and fittings.

236 Congress St., Boston, Mass.

We Carry in BOSTON STOCK for Immediate Shipment

CAST IRON BELL AND SPIGOT WATER PIPE AND FITTINGS
FLANGED PIPE in full and short lengths
WROUGHT PIPE

FRED A. HOUDLETTE & SON
(Incorporated)

40 Central Street, Boston, Mass.

Quotations furnished promptly for shipment from Foundry

SUMNER & DUNBAR

Manufacturers of and Dealers in
S. & G. Water Works Brass Goods
Byers' Wrought Iron Pipe
Service and Valve Boxes
Cast Iron Pipe and Fittings

12-18 Pittsburgh Street - - Boston, Mass.
Telephone, Liberty 1350

CEMENT LINED SERVICE PIPE

With Specially Adapted Lead-lined Fittings

Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.

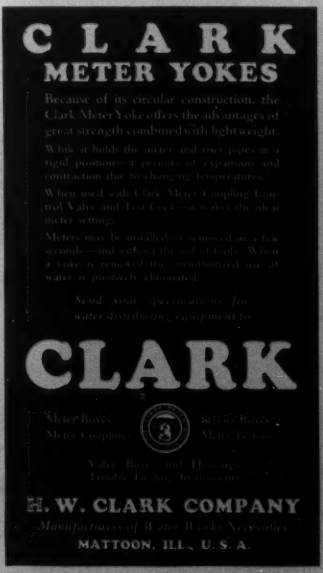
CEMENT LINED PIPE CO.
LYNN, MASS.

Water Works Contractors and Supply Houses!

Your card may be inserted as above at a rate of $12 per year.

A Classified Directory

of Advertisements is arranged for your convenience in the back of this Journal.


CLARK
METER YOKES
Because of its circular construction, the Clark Meter Yoke offers the advantages of great strength combined with light weight.
While it holds the meter and riser pipes in a rigid position—it permits of expansion and contraction due to changing temperatures.
When used with Clark Meter Coupling Control Valve and Test Cock—it makes the ideal meter setting.
Meters may be installed or removed in a few seconds—and without the aid of tools. When a yoke is removed the unauthorized use of water is positively eliminated.
Send your specifications for water distributing equipment to
CLARK
H. W. CLARK COMPANY
Manufacturers of Water Works Necessities
MATTOON, ILL., U. S. A.

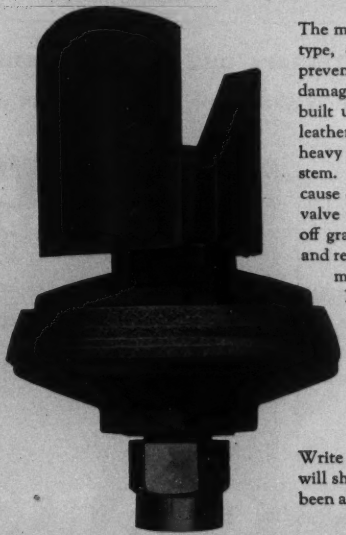
Another Special Feature!!

OF THE

MATHEWS MODERNIZED HYDRANT

Reg. U. S. Patent Office

THE COMBINATION MAIN AND DRAIN VALVE

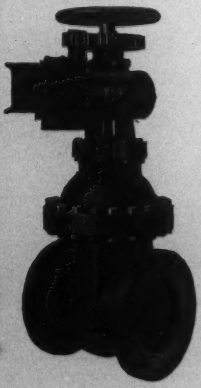


The main valve is the true compression type, closing *with* the pressure—thus preventing loss of water and resultant damage if the hydrant is broken. It is built up of the best oak tanned sole leather, held securely in place by a heavy bottom casting screwed onto the stem. It cannot work loose to leak or cause chatter. Being cone-shaped, the valve permits water to be turned on or off gradually, avoiding water hammer, and reducing the possibility of foreign matter lodging on the valve seat. Note the generously wide leather faced drain valve, assurance against leakage. It operates in a smooth bronze cylinder to prevent wear.

Write for complete description that will show you why the Mathews has been a leader for over half a century.

CAST IRON PIPE
SAND SPUN (Centrifugally Cast)
(Reg. U.S. Pat. Off.)
AND PIT CAST
GATE VALVES AND FITTINGS

R. D. WOOD & CO.
In business continuously since 1803
400 Chestnut St. Philadelphia



Ready —

and instantly responsive

WATER-WORKS engineers and fire chiefs are naturally careful to select only apparatus that has definitely proven its thorough dependability as well as efficiency of operation.

The designers of pumping stations and fire protection systems all over the country choose Kennedy Valves and Fire Hydrants because the performance of Kennedy products has proven them to be always ready — and instantly responsive.

It will pay you to investigate Kennedy design and performance. Kennedy Water Gates and Fire Hydrants are built to conform with American Water Works Specifications and their many special features are based on over half a century of experience in this field.

THE KENNEDY VALVE MFG. CO.

Elmira, N. Y.

Branches in principal cities

KENNEDY

VALVES~PIPE FITTINGS~FIRE HYDRANTS

THE STANDARD FOR 50 YEARS

Automatic Pressure Control Valves
Feed Water Filters
Portable Fire Hydrants
Hydraulic Engines
Hydraulic Engines—Booster Pumps

ROSS VALVE MFG. CO., INC. TROY, N. Y.

Health and Protection First

Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

50 Church Street New York City

HAYES PUMP AND MACHINERY CO.

94 PEARL ST., BOSTON, MASS.

Pumping Plant Contractors

CENTRIFUGAL, POWER, STEAM PUMPS

STEAM TURBINES
WATER WHEELS

ELECTRIC MOTORS
OIL ENGINES

GOLDEN-ANDERSON

Patent Automatic Cushioned Controlling Altitude Valves

We have enlightened many a water user in municipalities, in industrial plants and on railroads, as to the adaptability of these Golden-Anderson Valves, and as to their function of SAVING, and of eliminating troubles.

For automatically maintaining Uniform Stage of Water in Tank, Reservoir or Standpipes. Doing away with the annoyance of Freezing and Float Fixtures inside or outside of Tanks.

"Three Ways of Closing These Valves":
1st —Automatically, by water.
2nd—By Electricity, if desired.
3rd—By Hand

May also be arranged to automatically close when a break occurs in the mains. When necessary they may be so connected as to "work both ways" on a single line of pipe.

No valves or fixtures inside or outside.

Sizes to 24 in.

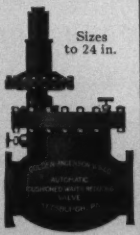
Remember!

"HOSTS OF REFERENCES"
Valves cushioned at all times by air and water
No water hammer or bursting mains

"Made with stop starter attachment for centrifugal pumps"

GOLDEN-ANDERSON
Pat. Automatic Cushioned Water Pressure Regulating Valves

1. Maintain a constant reduced pressure regardless of fluctuations on high pressure side.
2. Perfectly Cushioned by water and air. No metal-to-metal seats.
3. The best valve made for maintaining a constant low pressure where consumption is continuous.
4. Operates quickly or slowly as required — No attention necessary.
5. Positively no hammering or sticking.



Sizes to 24 in.

GOLDEN-ANDERSON
Patent Automatic Cushioned Controlling Float Valves

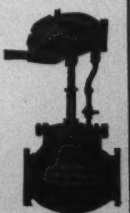
They carry a constant water level in feed water heaters by perfectly controlling the flow of makeup water.

Operated by protected enclosed copper float.

Cushioned by both air and water.

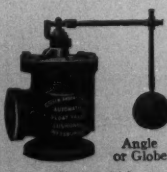
Operate without hammering, sticking or chattering. No metal-to-metal seats. Made angle or straightway.

Sizes 1 in. to 24 in.



GOLDEN-ANDERSON
Pat. Automatic Cushioned Water Float Valves

1. Automatically Maintain Uniform Water Levels in Tanks, Standpipes, etc.
2. Instantly Adjusted to Operate Quickly or Slowly.
3. Floats Swivel to any Angle — Most Satisfactory Float Valves Known.
4. No Metal-to-Metal Seats — No Water Hammer or Shock.
5. Cushioned by Water and Air.



Angle or Globe

Sizes to 24 in.

GOLDEN-ANDERSON
Patent Automatic Double Cushioned Check Valve

Sizes to 24 in. Angle or Globe

Automatically prevents reverse flow of pressure. Perfectly cushioned to prevent shock or hammer. Especially adapted for water works to prevent disastrous reverse flow of pressure due to pumps stopping. Arranged so that quick or slow operating may be obtained.

Golden-Anderson Valve Specialty Co., 1325 Fulton Bldg., Pittsburgh, Pa.

THE CHAPMAN VALVE MANUFACTURING COMPANY

Manufacturers of

Gate Valves Drip Valves

Gate Fire Hydrants

Corporation Cocks Curb Cocks

Anderson Couplings

Lead Pipe Connections

Trade

Mark

WRITE FOR OUR WATER-WORKS CATALOG

Main Office and Works
Indian Orchard, Mass.

BRANCH HOUSES

BOSTON, MASS. 141 High St.
NEW YORK CITY 180 Lafayette St.
PHILADELPHIA 1011 Filbert St.
CHICAGO 116 N. Jefferson St.

Type of Eddy Hydrant Popularly Used

More Than Sixty Years of Experience Goes Into All

EDDY

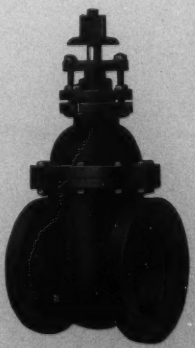
Hydrants and Valves

BUILT TO MEET EVERY EXACTING REQUIREMENT OF WATER-WORKS SERVICE

Practical water-works men instantly recognize the superior features of Eddy products. For instance, with the hydrant.

A damaged valve can be replaced in a few minutes — Water hammer is avoided by the valve closing against the pressure and the use of the cut-off under the valve, which gradually closes it —
Stems cannot be bent in closing the hydrant.
Nothing can lodge on the valve seat to prevent closing of the valve —
The Drip Rod can be removed without interfering with the hydrant in any manner —
The position of the stem of the hydrant indicates accurately the position of the valve —
Whatever can pass the valve opening will pass the standpipe —
No frost case necessary —
All of these points are explained thoroughly in our catalogue, which will pay you to study.

The Eddy Valve, Too



Has its distinctive and individual features. The double disk gates are free to adjust themselves in different positions every time the valve is closed, thereby keeping smooth and tight faces. And two bronze hooks on the ball loosely engage with the gates to prevent them from spreading at the top. The center bearing gates are forced to their seats with equal pressure at all points. There is a good deal more worth knowing about Eddy Valves. Further details will be sent for the asking.

Other Eddy Products

The Eddy line of water-works products also includes horisontal and vertical check valves, foot valves, hydraulically operated valves, indicator posts, etc.
All goods made by the Eddy Valve Company are manufactured exclusively at Waterford, New York.

WRITE FOR CATALOGUE

EDDY VALVE COMPANY

WATERFORD, N. Y., U. S. A.

DONALDSON IRON CO.

MANUFACTURERS
...OF...

CAST IRON PIPE

...AND...

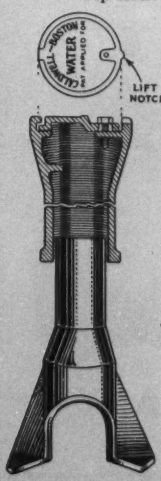
Special Castings for Water and Gas.
Also Flange Pipe and Fittings.

Boston Office:
CHARLES F. GLAVIN
24 Milk Street

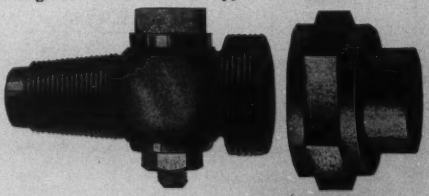
EMAUS,
LEHIGH COUNTY, PA.

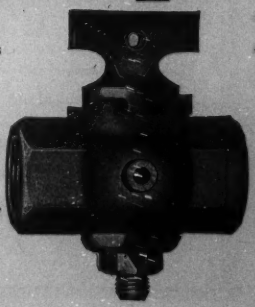
The "BEST" Cast Iron Curb Box

Top section is interchangeable with the "Slide Type" Buffalo Box



No change necessary in wrench or shut off keys





"CALDWELL" Water Works
Brass Goods, Curb and
Valve Boxes

None better and few as good

GEORGE A. CALDWELL CO.
Mattapan Square
BOSTON, MASS.

National-Boston Lead Co.

800 Albany St., Boston

Agents for

The Celebrated "ULCO"

LEAD WOOL

(Every Atom Pure Lead)

For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

As compared with the poured joint, in this respect, the superiority of **LEAD WOOL** is apparent.

Manufacturers of

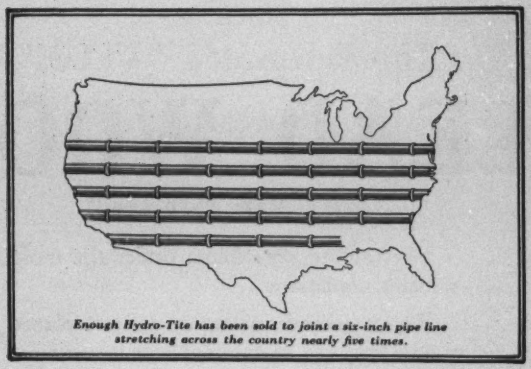
Lead Pipe, Tin Lined Lead Pipe, Pure Block-Tin Pipe, Solder, White Lead and Red Lead.

HIGHEST QUALITY SOFT BRANDS

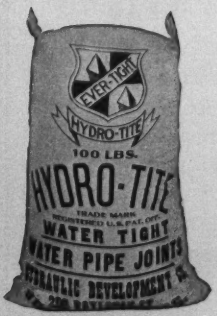
PIG LEAD

HYDRO-TITE

— *its record . . .*



Enough Hydro-Tite has been sold to joint a six-inch pipe line stretching across the country nearly five times.



HYDRO-TITE is always the same, comes in moisture proof, non-dusting bags, is shipped the day order is received. Every bag is subject to a guarantee which makes it impossible for you to lose by trying this modern pipe jointing material.

. . . over 21 years without a failure

Millions of joints in cast iron bell and spigot water pipe have been made with HYDRO-TITE.

In over 21 years not a single failure has been reported to us.

No wonder that year by year more waterworks men specify and use HYDRO-TITE and HYDRO-TITE equipment. They profit because HYDRO-TITE joints never blow out, leak 75% to 95% less than engineers specify for lead joints, withstand deflection and vibration, save 75% as compared with lead, require no caulking.

Write for the new HYDRO-TITE *data book, just issued*

Hydraulic Development Corporation

Main Sales Office:
50 Church Street, New York, N. Y.

General Offices and Works:
80 Boylston Street, Boston, Mass.

HYDRO-TITE

TODAY'S SELF-CAULKING WATER-PIPE JOINTING COMPOUND

How About DARLING VALVES?

This would be the typical reply of a Water Superintendent, familiar with Darling and other makes:

"The practical design, high character of metal and workmanship of the Darling Gate Valve limit trouble and up-keep cost to the minimum. When these kinds of expenses are considered, differences in initial cost are inconsequential."

What are the Outstanding Features Which Make Darling Valves so Desirable?

FIRST - - - Tight Cut-Off

The Discs in Darling Gate Valves are independent of each other and of the Wedges. They are free to revolve and change their position on the seat faces each time the Valve is closed. Unequal wear is avoided and the length of perfect service materially prolonged.

SECOND - - - Easy Operation

The result of simplicity of the working parts, the perfect alignment of the stem with the working parts and the positive releasing of the discs from the seats in opening the valve before the discs start to rise. Even the big horizonal type Darling Valves can be operated by one man.

THIRD - - - Durability

The very design of the Darling valve eliminates broken stems and other parts. It is always in operating condition. The same honesty of materials and workmanship that veteran water superintendents admired years ago are yours when you equip with Darlings.

The more quality you buy, the less you will spend for valves in the long run. Darling Gate Valves are known wherever valves are used as "the long-lived, dependable valves." They are worth their slightly higher cost.

Darling Valve & Manufacturing Company

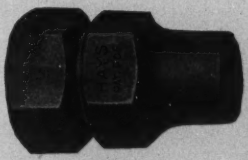
Williamsport, Pa.

NEW YORK LOS ANGELES OKLAHOMA CITY HOUSTON

OPEN
TRADE LUDLOW MARK
8,000,000
8,000,000
8,000,000
8,000,000
REASONS
Eight million Ludlow Valves and Hydrants giving good service throughout the world—eight million reasons for choosing Ludlow, noted for quality for over half a century.
The LUDLOW VALVE
Manufacturing Co.
TROY N.Y.
TRADE MARK

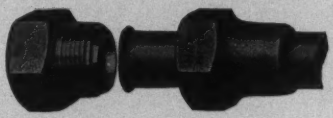
The Hays Copper Plumbing Method

Regular Corporation Stop



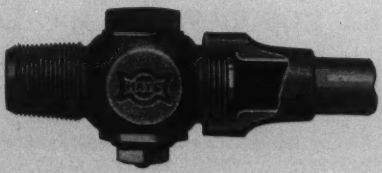
Adapter

In making an installation with Hays Copper Service Fittings the regular Corporation Stops can be used in conjunction with the adapter. It is not necessary to procure new mandrels, as the Corporation Stops are inserted with the regular mandrels, in the usual manner, after which the adapter is attached.



Open View of Adapter

These adapters are made with Female Thread for Increased I. P., Water Works Standard or Lead Flange.



To use standard Corporation Stops with Increased I. P. or Water Works Standard Thread, and where a direct connection of the Corporation Stop and Copper Pipe is desired, the above stop has been designed. (See cut above for sectional view of joint.) These stops permit a Hays 90° seal with the use of regular male mandrels.

Write for complete details of

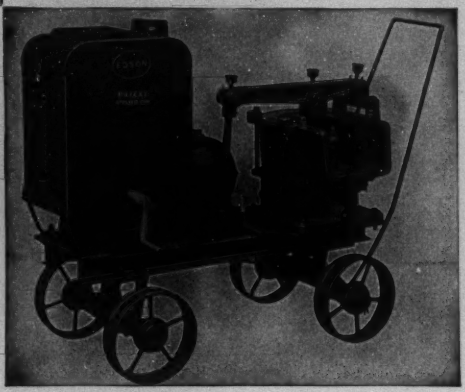
The Hays Copper Plumbing Method for Water Works and House Plumbing

Hays Manufacturing Co. Erie, Pa.

EDSON MFG. CORP.

DIAPHRAGM PUMP SPECIALTIES

Hand Pumps. Heavy Duty and
Light Portable Power Pump Outfits



EDSON

Special Suction Hose

Red Seal Diaphragms

Pump Accessories

Main Office and Works:
49 D Street
South Boston, Mass.
Tel. SOU th Boston 3041
New York: 142 Ashland Place, Brooklyn

Warren Foundry & Pipe Corp.

ALSO

Warren Pipe Co. of Mass., Inc.

SALES OFFICES

11 BROADWAY, NEW YORK
75 FEDERAL STREET, BOSTON, MASS.

Manufacturers of

CAST IRON PIPE

Flanged Pipe *Flexible Joint Pipe*

Bell and Spigot Pipe

Special Castings *Short Body B. & S. Specials*

Warren (WF) Spun Centrifugally Cast Iron Pipe

WORKS: PHILLIPSBURG, N. J. and EVERETT, MASS.

Large Stock Enables Us to Make Prompt Shipments

CLASSIFIED DIRECTORY OF ADVERTISEMENTS.

PAGE

AIR COMPRESSORS.
Hayes Pump and Machinery Co. . . . xxx
Murray Iron Works Co. . . . xx
Worthington Pump & Machinery Corp. . . . viii

BOILER SETTINGS.
Starkweather & Broadhurst . . . xix

BOILERS, STEAM.
Mazzur, F. A., & Co. . . . xvii
Murray Iron Works Co. . . . xx
Starkweather & Broadhurst . . . xix

BRASS GOODS.
(See also Pipe, Brass.)
Caldwell, George A., Co. . . . xxxiv
Cement Lined Pipe Co. . . . xxvii
Hays Mfg. Co. . . . xxxix
Mueller Co. . . . xvi
Pierce-Perry Co. . . . xxvii
Sumner & Dunbar . . . xxvii
The A. P. Smith Mfg. Co. . . . xix
Union Water Meter Co. . . . xi

CALKING MACHINERY AND TOOLS.
Mueller Co. . . . xvi
The A. P. Smith Mfg. Co. . . . xix

CAST IRON PIPE. (See Pipe, Cast Iron.)

CEMENT LINED PIPE. (See Pipe, Cement Lined.)

CHEMICAL FEED APPARATUS.
Wallace and Tiernan Co., Inc. . . . xxiii

CHLORINATORS.
Wallace & Tiernan Co., Inc. . . . xxiii

CLEANING WATER MAINS.
General Pipe Cleaning Co. . . . iii
National Water Main Cleaning Co. . . . xxx

COCKS, CURB AND CORPORATION.
Caldwell, George A., Co. . . . xxxiv
Hays Mfg. Co. . . . xxxix
Mueller Co. . . . xvi
Pierce-Perry Co. . . . xxvii
Sumner & Dunbar . . . xxvii
The A. P. Smith Mfg. Co. . . . xix
Union Water Meter Co. . . . xi

CONCRETE PIPE.
(See Pipe, Concrete.)

CONDENSERS.
Hayes Pump and Machinery Co. . . . xxx
Mazzur, F. A., & Co. . . . xvii
Starkweather & Broadhurst . . . xix
Worthington Pump & Machinery Corp. . . . viii

CONSTRUCTION EQUIPMENT.
Edson Mfg. Corp. . . . xl

CONTRACTORS.
Ferullo, G., Co. . . . iii
Hughes, Edward F . . . iii
National Water Main Cleaning Co. . . . xxx

CURB BOXES.
Bingham and Taylor . . . v
Caldwell, George A., & Co. . . . xxxiv
Clark, H. W., Co. . . . xxvii
Hays Mfg. Co. . . . xxxix
Mueller Co. . . . xvi
Sumner & Dunbar . . . xxvii

CURB AND VALVE BOX FINDERS.
Caldwell, George A., Co. . . . xxxiv

DIAPHRAGMS, PUMP.
Edson Mfg. Corp. . . . xl

ENGINEERS.
Ambursen Construction Co. . . . ii
Barbour, Frank A. . . . ii
Barrows, H. K. . . . ii
Conard, William R. . . . ii
Fay, Spofford & Thorndike . . . ii
Fuller & McClintock . . . ii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*.

ENGINEERS — *Continued* PAGE

Hazen & Everett . . . ii
Main, Charles T. . . . ii
Metcalf & Eddy . . . ii
Pirnie, Malcolm . . . iii
Symonds, Henry A. . . . iii
Thorpe, Lewis D. . . . iii
Weston & Sampson . . . ii

ENGINES.
(See Pumps and Pumping Engines.)

ERECTORS, WATER WORKS AND POWER MACHINERY.
Hayes Pump and Machinery Co. . . . xxx
Mazzur, F. A., & Co. . . . xvii
Starkweather & Broadhurst . . . xix
Turbine Equipment Co. . . . xxii

FEED WATER HEATERS.
Hayes Pump and Machinery Co. . . . xxx
Mazzur, F. A., & Co. . . . xvii
Ross Valve Mfg. Co. . . . xxx
Starkweather & Broadhurst . . . xix
Worthington Pump & Machinery Corp. . . . viii

FILTER RATE CONTROLLERS AND GAGES.
(See Rate Controllers.)

FILTERS AND WATER SOFTENING PLANTS.
Ross Valve Mfg. Co. . . . xxx

FILTRATION PLANT EQUIPMENT.
Builders Iron Foundry . . . ix
Ross Valve Mfg. Co. . . . xxx
Wallace & Tiernan Co., Inc. . . . xxiii

FLEXIBLE JOINTS.
U. S. Cast Iron Pipe and Foundry Co. . . . Facing back cover

FURNACES, ETC.
Mueller Co. . . . xvi
The A. P. Smith Mfg. Co. . . . xix
The Leadite Co. . . . Back cover

GAGES, SURFACE, RESERVOIR AND SPECIAL WATER WORKS.
Builders Iron Foundry . . . ix

GAS ENGINES.
Worthington Pump & Machinery Corp. . . . viii

GATE VALVES. (See Valves.)

HOSE, SUCTION AND CONDUCTION.
Edson Mfg. Corp. . . . xl

HYDRANTS, FIRE.
Chapman Valve Mfg. Co. . . . xxxii
Eddy Valve Co. . . . xxxiii
Fox, John, & Co. . . . xxvi
Kennedy Valve Mfg. Co. "Newtype" . . . xxix
Ludlow Valve Mfg. Co. . . . xxxviii
Rensselaer Valve Co. "Corey" . . . xxv
Ross Valve Mfg. Co. . . . xxx
The A. P. Smith Mfg. Co. . . . xix
Wood, R. D., & Co. . . . xxviii

HYDRANTS, SPRINKLING AND FLUSHING.
Mueller Co. . . . xvi

INSPECTION OF MATERIALS.
Conard, William R. . . . ii

LEAD.
National-Boston Lead Co. . . . xxxv

LEAD PIPE.
(See Pipe, Lead.)

LEAD WOOL.
National-Boston Lead Co. . . . xxxv

LEAK FINDERS.
Pitometer Co. . . . iii

LIQUID CHLORINE.
(See Chlorine, Liquid.)

METERS, WATER AND OIL.
Badger Meter Mfg. Co. . . . xv
Buffalo Meter Co. . . . x
Builders Iron Foundry . . . ix
Gamon Meter Co. . . . xiii
Hersey Mfg. Co. . . . iv
National Meter Co. . . . xiv
Neptune Meter Co. . . . vi

CLASSIFIED DIRECTORY OF ADVERTISEMENTS (*Continued*).

METERS — *Continued* PAGE
Pitometer Co. . . . iii
Pittsburgh Equitable Meter Co. . . . vii
Simplex Valve & Meter Co. . . . xii
Union Water Meter Co. . . . xi
Worthington Pump and Machinery Corp. . . . viii

METER COUPLINGS.
Ford Meter Box Co. . . . xix
Mueller Co. . . . xvi

METERS (VENTURI TYPE).
Builders Iron Foundry . . . ix
National Meter Co. . . . xiv
Simplex Valve & Meter Co. . . . xii

METER BOXES.
Bingham and Taylor . . . v
Clark, H. W., Co. . . . xxvii
Ford Meter Box Co. . . . xix

METER TESTERS.
Ford Meter Box Co. . . . xix
Clark, H. W., Co. . . . xxvii
Mueller Co. . . . xvi

OIL ENGINES, DIESEL.
Fairbanks-Morse & Co. . . . xxi
Hayes Pump and Machinery Co. . . . xxx
Worthington Pump and Machinery Corp. . . . viii

PIPE, BRASS.
Pierce-Perry Co. . . . xxvii
Sumner & Dunbar . . . xxvii

PIPE, CAST IRON (AND FITTINGS).
Builders Iron Foundry . . . ix
Central Foundry Co. . . . xix
Donaldson Iron Co. . . . xxxiv
Fox, John, & Co. . . . xxvi
Houdlette, Fred A., & Son . . . xxvii
McWane Cast Iron Pipe Company . . . xxv
U. S. Cast Iron Pipe and Foundry Co. . . . Facing back cover
Warren Foundry and Pipe Co. . . . xl
Wood, R. D., & Co. . . . xxviii

PIPE, CEMENT LINED.
Cement Lined Pipe Co. . . . xxvii
Union Water Meter Co. . . . xi

PIPE, CONCRETE.
Lock Joint Pipe Co. . . . Facing front cover

PIPE CUTTING MACHINES.
The A. P. Smith Mfg. Co. . . . xix

PIPE JOINTING MATERIAL.
Atlas Mineral Products Co. . . . xviii
Hydro-Tite . . . xxxvi
The Leadite Co. . . . Back cover

PIPE, LEAD.
National-Boston Lead Co. . . . xxxv

PIPE, LEAD LINED.
Lead Lined Iron Pipe Co. . . . xxvi

PIPE, TIN LINED.
Lead Lined Iron Pipe Co. . . . xxvi

PIPE, UNIVERSAL.
Central Foundry Co. . . . xix

PIPE, WROUGHT IRON AND STEEL.
Biggs Boiler Works Co. . . . xxiv
Pierce-Perry Co. . . . xxvii
Sumner & Dunbar . . . xxvii

PITOMETERS.
Pitometer Co. . . . iii

PRESSURE REGULATORS.
Caldwell, George A., Co. . . . xxxiv
Golden-Anderson Valve Specialty Co. . . . xxxi
Mueller Co. . . . xvi
Ross Valve Mfg. Co. . . . xxx
Union Water Meter Co. . . . xi

PROVERS, WATER.
Pittsburgh Equitable Meter Co. . . . vii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS *(Continued)*.

PUMPS AND PUMPING ENGINES. — Page
- Edson Manufacturing Corp. . . . xl
- Fairbanks-Morse & Co. . . . xxi
- Hayes Pump and Machinery Co. . . . xxx
- Massur, F. A., Co. . . . xvii
- Murray Iron Works Co. . . . xx
- Ross Valve Mfg. Co. . . . xxx
- Starkweather & Broadhurst . . . xix
- Turbine Equipment Co. . . . xxii
- Wood, R. D., & Co. . . . xxviii
- Worthington Pump and Machinery Corp. . . . viii

RATE CONTROLLERS.
- Builders Iron Foundry . . . ix
- Simplex Valve & Meter Co. . . . xii

SERVICE CLAMPS, GALVANIZED.
- Mueller Co. . . . xvi

SLEEVES AND VALVES, TAPPING.
- Ludlow Valve Mfg. Co. . . . xxxviii
- Mueller Co. . . . xvi
- Rensselaer Valve Co. . . . xxv
- The A. P. Smith Mfg. Co. . . . xix

SPECIFICATIONS, FORM AND METER RATE SHEETS
- New England Water Works Association . . . xxvi

STACKS.
- Starkweather & Broadhurst . . . xix

SULPHATE OF ALUMINA. (See Alum.)

SUPPLIES AND TOOLS.
- Caldwell, George A., Co. . . . xxxiv
- Hays Mfg. Co. . . . xxxix
- Mueller Co. . . . xvi
- Pierce-Perry Co. . . . xxvii
- Sumner & Dunbar . . . xxvii
- The A. P. Smith Mfg. Co. . . . xix
- The Leadite Co. . . . Back cover

TANK PAINT.
- M. B. Main . . . xxv

TANKS, STEEL.
- Murray Iron Works Co. . . . xx

TAPPING MACHINES.
- Hays Mfg. Co. . . . xxxix
- Mueller Co. . . . xvi
- The A. P. Smith Mfg. Co. . . . xix

TAPPING SLEEVES. (See Sleeves and Valves, Tapping.)

UNIVERSAL PIPE. (See Pipe, Universal.)

VALVE BOXES.
- Bingham and Taylor . . . v
- Clark, H. W., Co. . . . xxvii
- Ford Meter Box Co. . . . xix
- Rensselaer Valve Co. . . . xxv
- Wood, R. D., & Co. . . . xxviii

VALVE INSERTING MACHINES.
- The A. P. Smith Mfg. Co. . . . xix

VALVE SPECIALTIES.
- Golden-Anderson Valve Specialty Co. . . . xxxi

VALVES, GATE.
- Chapman Valve Mfg. Co. . . . xxxii
- Darling Valve & Mfg. Co. . . . xxxvii
- Eddy Valve Co. . . . xxxiii
- Fox, John, & Co. . . . xxvi
- Kennedy Valve Mfg. Co. . . . xxix
- Ludlow Valve Mfg. Co. . . . xxxviii
- Rensselaer Valve Co. . . . xxv
- Ross Valve Mfg. Co. . . . xxx
- Simplex Valve & Meter Co. . . . xii
- The A. P. Smith Mfg. Co. . . . xix
- Wood, R. D., & Co. . . . xxviii

VALVES, REGULATING.
- Golden-Anderson Valve Specialty Co. . . . xxxi
- Mueller Co. . . . xvi
- Ross Valve Mfg. Co. . . . xxx
- Union Water Meter Co. . . . xi

WATER WASTE DETECTION.
- Pitometer Co. . . . iii
- Simplex Valve & Meter Co. . . . xii

WROUGHT IRON PIPE. (See Pipe, Wrought Iron and Steel.)

46 miles of DeLavaud Pipe are in use for gas and water mains

The progressive spirit of Springfield, Massachusetts is exemplified by a beautiful civic center with a magnificent campanile tower. Springfield's progressiveness is also evidenced by its gas and water systems for which 46 miles of deLavaud pipe have been specified and laid.

For deLavaud pipe is the strongest pipe ever cast. It is a tough pipe too. The metal is dense and fine-grained—remarkably free from slag, blow holes and weakening impurities. Tests conducted by disinterested testing laboratories have proved that deLavaud pipe is at least 25% stronger than good pit cast pipe.

DeLavaud pipe is produced by pouring molten iron into a rapidly revolving cylindrical mold. Centrifugal force holds the metal against the sides of the mold and drives out impurities with a force many times greater than gravity. DeLavaud pipe is a modern pipe for modern conditions and present-day high-pressures. Ask for facts and figures. The new deLavaud Handbook gives detailed information. Write for a free copy today.

The self-centering shoulder in the deLavaud bell eliminates the requirement of a head. In laying deLavaud pipe it is only necessary to place the spigot of one pipe within the bell of the next, sliding the pipe forward until it rides upon the taper and automatically centers itself.

United States Pipe and Foundry Co., Burlington, N.J.

Sales Offices: New York, Philadelphia, Pittsburgh, Cleveland, Buffalo, Chicago, Dallas, Birmingham, Kansas City, Minneapolis, Seattle, San Francisco, Los Angeles

Our use here of "Q-Check" trademark of The Cast Iron Pipe Research Association

The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness. ALL MEMBERS OF THE ASSOCIATION RECEIVE THE JOURNAL IN PART RETURN FOR THEIR ANNUAL DUES; to all others the subscription is four dollars per annum.

TO ADVERTISERS

THE attention of parties dealing in goods used by Water Departments is called to the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION as an advertising medium.

Its subscribers include the principal WATER WORKS ENGINEERS and CONTRACTORS in the United States. The paid circulation is **1100** COPIES.

Being filled with original matter of the greatest interest to Water Works officials, it is PRESERVED and constantly REFERRED TO BY THEM, and advertisers are thus more certain to REACH BUYERS than by any other means.

The JOURNAL is not published as a means of revenue, advertisements being inserted solely to help meet the large expense of publication.

ADVERTISING RATES.

One page, one year, four insertions	Eighty Dollars.
One-half page, one year, four insertions	Fifty-six Dollars.
One-fourth page, one year, four insertions	Thirty-six Dollars.
One-twelfth page (card), one year, four insertions	Twelve Dollars.
One page, single insertion	Forty Dollars.
One-half page, single insertion	Thirty Dollars.
One-fourth page, single insertion	Twenty Dollars.

Size of page, 4½ x 7½ net.

A sample copy will be sent on application.

For further information, address,

GORDON M. FAIR, Editor,
112 PIERCE HALL,
HARVARD UNIVERSITY,
CAMBRIDGE, MASS.

The Rand Avil Press
SAMUEL USHER
BOSTON, MASSACHUSETTS

LEADITE

Philadelphia Suburban Water Company —*uses* LEADITE *exclusively*

This well-known Water Company, one of the C. H. Geist properties, supplies a population of about 315,000 persons through approximately 900 miles of water mains.

It is a significant fact that they have USED LEADITE EXCLUSIVELY on approximately 230 miles of their water mains laid in the last 4½ years (sizes up to 24 in. inclusive, and pressures averaging 60 lb. per sq. in.—with maximum considerably above that figure). In fact, even prior to 1925, this Company used LEADITE extensively.

The daily per capita consumption of water is slightly under 60 gallons, which includes Domestic, Commercial and Industrial users — also fire, flushing and municipal purposes. This figure also includes all losses by leakage. These figures are excellent proof of tightness of pipe lines.

Mr. Carleton E. Davis* is Manager of the Philadelphia Suburban Water Company.

*Mr. Davis is a Past President of both the American Water Works Association and the New England Water Works Association — also former Chief Engineer of Philadelphia Bureau of Water for 11 years.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 30 years.
Saves at least 75%

THE LEADITE COMPANY
Land Title Bldg. Philadelphia, Pa.

No Caulking